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A HALF-CENTURY OF EVOLUTION, WITH SPECIAL REFERENCE TO THE EFFECTS OF GEOLOGICAL CHANGES ON ANIMAL LIFE.[1]

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ONLY a little less than fifty years have passed since the publication of Darwin's *Origin of Species*, and the general acceptance by naturalists of the theory of descent. Since 1848 the sciences of embryology, cytology, and comparative anatomy based on embryology, or, as it is now called, morphology, have been placed on a firm foundation. It is but little over half a century since the uniformitarian views of Lyell were promulgated. The cell doctrine was born in 1839; the view that protoplasm forms the basis of life was generally received forty years since; fifty years ago the doctrine of the conservation of forces was worked out, and already by this time had the idea of the unity of nature dominated the world of science.

On the fiftieth anniversary, therefore, of our Association it may not be out of place, during the hour before us, first, briefly

[1] Address of the Vice-President and Chairman of Section F, Zoölogy, at the fiftieth anniversary meeting of the American Association for the Advancement of Science, Boston, August, 1898.

to inquire into the present state of evolution and its usefulness to zoölogists as a working theory, and then to dwell more at length on the subject of the effect of geological changes on animal life.

The two leading problems which confront us as zoölogists are: What is life? and How did living beings originate? We must leave to coming centuries the solution of the first question, if it can ever be solved; but we can, as regards the second, congratulate ourselves that, thanks to Lamarck, Darwin, and others, in our day and generation a reasonable and generally accepted solution has been reached.

Time will not allow us to attempt to review the discoveries and opinions which have already been discussed by the founders and leaders of the different schools of evolutionary thought, and which have become the common property of biologists, and are rapidly permeating the world's literature.

It may be observed at the outset that, if there is any single feature which differentiates the second from the first half of this century, it is the general acceptance of the truth of epigenetic evolution as opposed to the preformation or incasement theory, which lingered on and survived until a late date in the first half of the present century.[1] The establishment of the

[1] The theory of incasement (*emboîtement*), propounded by Swammerdam in 1733, was that the form of the larva, pupa, and imago of the insects preëxisted in the egg, and even in the ovary; and that the insects in these stages were distinct animals contained one inside the other, like a nest of boxes, or a series of envelopes one within the other; or, in his words: "Animal in animali, seu papilio intra erucam reconditus." Réaumur (1734) also believed that the caterpillar contained the form of the chrysalis and butterfly, saying: "Les parties des papillon cachées sous le fourreau de chenille sont d'autant plus faciles à trouver que la transformation est plus proche. Elles y sont néanmoins de tout temps." He also believed in the simultaneous existence of two distinct beings in the insect. "Il serait très curieux de connaître toutes les communications intimes qui sont entre la chenille et le papillon. . . . La chenille hache, broye, digère les aliments qu'elle distribué au papillon; comme les mères préparent ceux qui sont portés aux fœtus. Notre chenille en un mot est destinée à nourrir et à défendre le papillon qu'elle renferme." (Tome i, 8e Mémoire, p. 363.)

It was not until 1815 that Herold exploded this error, though Kirby and Spence in 1828, in their *Introduction to Entomology*, combated Herold's views and maintained that Swammerdam was right. As late as 1834, a century after Swammerdam, Lacordaire in his *Introduction à l'Entomologie*, declared that "a caterpillar is not a simple animal, but compound," and he actually goes so far as to say that

epigenetic view is largely due to exact investigation and modern methods of research, but more especially to the results of modern embryology and to the fairly well digested facts we now have relating to the development of one or more types of each class of the animal kingdom.

To use a current phrase, the evolution theory as now held has come to stay. It is the one indispensable instrument on which the biologist must rely in doing his work. It is now almost an axiomatic truth that evolution is the leaven which has leavened the whole lump of human intellectual activity. It is not too much to claim that evolutionary views, the study of origins, of the beginning of organic life, the genesis of mental phenomena, of social institutions, of the cultural stages of different peoples and of their art, philosophy, and religion, — that this method of natural science has transformed and illuminated the philosophy of the present half-century.[1]

"a caterpillar at first scarcely as large as a bit of thread, contains its own teguments threefold and even eightfold in number, besides the case of a chrysalis, and a complete butterfly, all lying one inside the other." This view, however, we find is not original with Lacordaire, but was borrowed from Kirby and Spence without acknowledgment. These authors, in their *Introduction to Entomology* (1828), combated Herold's views and stoutly maintained the old opinions of Swammerdam. They based their opinions on the fact, then known, that certain parts of the imago occur in the caterpillar. On the other hand, Herold denied that the successive skins of the pupa and imago existed as germs, holding that they are formed successively from the *rete mucosum*, which we suppose to be the hypodermis of later authors. In a slight degree the Swammerdam-Kirby and Spence doctrine was correct, as the imago does arise from germs, *i.e.*, the imaginal discs of Weismann, while this was not discovered by Herold, though they do at the outset arise from the hypodermis, his *rete mucosum*. Thus there was a grain of truth in the Swammerdam-Kirby and Spence doctrine, and also a mixture of truth and error in the opinions of Herold.

The discovery by Weismann of the imaginal discs or buds of the imago in the maggot of the fly, and his theory of histolysis, or of the more or less complete destruction of the larval organs by a gradual process, and his observation of the process of building up of the body of the imago from the previously latent larval buds, was one of the triumphs of modern biology. It is therefore not a little strange to see him at the present day advocating a return to the preformation views of the last century in the matter of heredity. Of course it goes without saying, as has always been recognized, that there is something in the constitution of one egg which predestines its becoming an insect, and in that of another which destines it to produce a chick.

[1] It is worthy to mention that just fifty years ago, in his *Future of Science*, written in 1848, at the age of 25, Renan, who first among philosophers and stu-

It is naturally a matter of satisfaction and pride to us as zoölogists that, though evolution has been in the air from the days of the Greek philosophers down to the time of Lamarck, the modern views as to the origin of variations, of adaptation, of the struggle for existence, of competition, and the preservation of favored organs or species by selection, are the products of single-minded zoölogists like Darwin, Wallace, Fritz Müller, Semper, and Haeckel. It is the work of these men, supplemented by the labors of Spencer and of Huxley, and the powerful influence of the botanists Hooker and Gray, all of whom contributed their lifelong toil and efforts in laying the foundation stones of the theory, which has brought about its general acceptance among thinking men. It is these naturalists, some of them happily still living, who had worked out the principle of evolution from the generalized to the specialized, from the simple to the complex, from chaos to cosmos.

The doctrine of evolution has been firmly established on a scientific basis by many workers in all departments of biology, and found not only to withstand criticism from every quarter, but to be an indispensable tool for the investigator. The strongest proof of its genuine value as a working theory is that it has, under the light shed by it, opened up many an avenue of inquiry leading into new fields of research. It is based on the inductive method, the observation and arrangement of a wide series of facts. Moreover, it explains a vast

dents of comparative philology adopted the scientific method, *i.e.*, the patient investigation of as wide a range of facts as possible, wrote: "I am convinced that there is a science of the origins of mankind, and that it will be constructed one day, not by abstract speculation, but by scientific researches. What human life in the actual condition of science would suffice to explore all the sides of this single problem? And still, how can it be resolved without the scientific study of the positive data? And if it be not resolved, how can we say that we know man and mankind? He who would contribute to the solution of this problem, even by a very imperfect essay, would do more for philosophy than by half a century of metaphysical meditation" (p. 150). Again he says: "The great progress of modern thought has been the substitution of the category of *evolution* for the category of the *being;* of the conception of the relative for the conception of the absolute, of movement for immobility. Formerly everything was considered as 'being' (an accomplished fact); people spoke of law, of religion, of politics, of poetry in an absolute fashion. At present everything is considered as in the process of formation" (p. 169).

complex of facts, and enables us to make predictions, the true test of a scientific theory. Biology is not an exact science, hence the theory is not capable of demonstration like a problem in mathematics, but is based on probabilities, the circumstantial evidence being apparently convincing to every candid, well-trained mind.

The methods and results of natural science, based as they now are on evolutional grounds, have, likewise, appealed to the historian, the philologist, the sociologist, and the student of comparative religion, whose labors begin with investigations into the origins.

It goes without saying that, thanks to the initiative of the above-named zoölogists, every department of intellectual work and thought has been rejuvenated and rehabilitated by the employment of the modern scientific method. All inquiring minds appreciate the fact that, throughout the whole realm of nature, inorganic as well as organic, physical, mental, moral, and spiritual, there was once a beginning, and that from a germ, by a gradual process of differentiation or specialization, the complex fabric of creation has, by the operation of natural laws and forces, been brought into being. All progress is dependent on this evolutionary principle, which involves variation, adaptation, the disuse or rejection of the unfit, the use or survival of the fittest, together with the mechanical principle of the utmost economy of material.

Though the human mind has its limitations and the chief arguments for evolution have been drawn from our observations of the history of our own planet and of the life existing upon it, the nebular hypothesis teaches us that the same process has determined the origin of other worlds than ours, and applies in fact to all the other members of our solar system, while with little doubt the principle may be extended to the entire universe.

At all events, evolutionary modes of thinking have now become a second nature with philosophic, synthetic minds, and to such any other view is inconceivable. We teach evolution in our colleges and universities, and the time is rapidly approaching, and in some instances has already come, when nature studies and the facts of biology forming the grounds of the

evolutionary idea will be taught in our primary and secondary schools.

The rapidity with which evolutionary conceptions have taken root and spread may be compared to the rankness of growth of a prepotent plant or animal on being introduced into a new territory where it is free from competition. It has indeed swept everything before it, occupying a field of thought which hitherto had been unworked by human intelligence.

The immediate effect, and a very happy one, of the acceptance of the theory of descent on working zoölogists is to broaden their minds. Collectors of insects and shells or of birds and mammals, instead of being content simply to acquire specimens for their cabinets, are led to look during their field excursions for examples of protective mimicry, or to notice facts bearing on the immediate cause of variation. Instead of a single pair of specimens, it is now realized that hundreds and even thousands collected from stations and habitats wide apart are none too many for the study of variation as now pursued.

The race of "species grinders" is diminishing, and the study of geographical distribution, based as it is on past geographical changes and extinctions, is now discussed in a far more philosophical way than in the past. The most special results of work in cytology and morphology are now affording material for broad work in phylogeny and heredity.

On the other hand, it must be confessed that, as the result of the acceptance of evolutionary views, our literature is at times flooded with more or less unsound hypotheses, some tedious verbiage and long-winded, aërial discussions, based rather on assumptions than on facts. But on the whole, perhaps, this is a healthy sign. Too free, exuberant growths will be in the long run lopped off by criticism.

One tendency should be avoided by younger students, that of too early specialization, and of empirical work without a broad survey of the whole field. In some cases our histologists and morphologists rise little above the intellectual level of species describers. Expert in the use of the microtome and of reagents, they appear to have but little more general scientific or literary culture than high-class mechanics. The chief anti-

dote, however, to the danger of narrowness is the lessons derived from evolutionary thought and principles.

Finally, as a proof of the value of evolutionary ideas to the present generation, let us suppose for a moment, if it were conceivable, that they should be blotted out. The result, it is safe to say, would be equivalent to the loss of a sense.

It is a matter of history that when a new idea or principle, or a new movement in philosophy or religion, arises, it at first develops along the line of least resistance; the leaders of the new thought acquire many followers or disciples. Soon the latter outstrip their teachers, and go to greater extremes; modifications of the original simple condition or theory occur, and as the final result there arise schisms and differentiations into new sects. This has happened in science, and already we have evolutionists divided into Lamarckians and Darwinians, with a further subdivision of them into Neolamarckians and Neodarwinians, while the latter are often denominated Weismannians. Some prefer to rely on the action of the primary factors of evolution, others believe that natural selection embraces all the necessary factors, while still others are thoroughly persuaded of its inadequacy.

The result of this analytical or differentiating process will probably be an ultimate synthesis, a belief that there is a complex of factors at work. Of these factors those originally indicated by Lamarck, with the supplementary ones of competition and natural selection bequeathed by Darwin, are the most essential and indispensable, and it is difficult to see how they can be displaced by other views. Meanwhile all agree, and it was never more firmly established than at this moment, that there is and always has been unceasing energy, movement, and variation, a wonderful adaptation and harmony in nature between living beings and their surroundings.

The present status of evolution in its different phases or attitudes since the time of the appearance of Darwin's *Origin of Species* may be roughly pointed out as follows: —

1. The claim by some thinkers of the inadequacy of Darwinism as such, or natural selection, to account for the rise of new species, and the assignment of this factor to what they

believe to be its proper place among the other factors of organic evolution.

2. The renascence of Lamarckism under the name of Neolamarckism, being Lamarckism in its modern form. This school relies on the primary factors of evolution, on changes in the environment, such as the agency of the air, light, heat, cold, changes in climate, use and disuse, isolation, and parasitism, while it regards natural, sexual, physiological, germinal, and organic selection, competition or its absence, and the inheritance of characters acquired during the lifetime of the individual, as secondary factors, calling into question the adequacy of natural selection as an initial factor.

3. The rise of the Neodarwinian school. While Darwin soon after the publication of the *Origin of Species* somewhat changed his views as to the adequacy of natural selection, and favored changes in the surroundings, food, etc., as causes of variation, his successors, Wallace, Weismann, and others, believe in the "all-sufficiency" of natural selection. Weismann also invokes panmixia, or the absence of natural selection, as an important factor; also amixia, and denies the principle of inheritance of acquired characters, or use-inheritance.

4. A third school or sect has arisen under the leadership of Weismann, who advocates what is in its essence apparently a revival of the exploded preformation, incasement, or "evolution" theory of Swammerdam, Bonnet, and Haller, as opposed to the epigenetic evolutionism of Harvey, Wolff, Baer, and the majority of modern embryologists. On the other hand, there are some embryologists who appear to accept the combined action of epigenesis and evolution in development.

5. Attention has been concentrated on the study of variations and of their cause. Opinion is divided as to whether variation is fortuitous, or definite and determined. Many now take exception to the view, originally held by Darwin, that variations are purposeless and fortuitous, believing that they are, for example, dependent on changes in the environment which were determined in early geological periods. For definite variation, Eimer proposes the term orthogenesis. Minute variations dependent on climatic and other obscure

and not readily appreciable causes are now brought out clearly by a system of varied and careful quantitative measurements.

6. More attention than formerly is given to the study of dynamical evolution, or kinetogenesis; to the effect of external stimuli, such as intermittent pressure, mechanical stresses and tensions by the muscles, etc., on hard parts. Originally suggested by Herbert Spencer, that the ultimate cause or mechanical genesis of the segmentation of the vertebrate skeleton was due to transverse strains, the segmentation of the bodies of worms and arthropods, as well as of vertebrates, has been discussed by recent workers (Ryder, Cope, Meyer, Tornier, Hirsch, and others). Here should be mentioned the work done in general physiology, or morphogenesis, by Verworm, Davenport, and others. Also the discoveries of Pasteur, and the application by Metschnikoff and of Kowalevsky of phagocytosis to the destruction and renewal of tissues during metamorphosis, bear closely on evolutional problems.

7. A new field of research founded by Semper, Vilmorin, and Plateau, and carried on by De Varigny, is that of experimental evolution, involving the effects of artificial changes of the medium, including temperature, food, variation in the volume of water and of air, absence of exercise, movement, etc. Also should be added horticultural experiments which have been practised for many years, as well as the results of acclimatization.

Here should be mentioned the experiments bearing on the mechanics of development (Entwickelungsmechanik der Organismen), or experimental embryology, of Oscar Hertwig, Roux, Driesch, Morgan, and others, and the curious results of animal grafting and of mutilations of the embryos, obtained by Born and others, as well as the regeneration of parts. The remarkable facts of adaptation to new and unfavorable conditions of certain embryos are as yet unexplained, and have led to considerable discussion and research.

8. The *a priori* speculations of Darwin, Galton, Spencer, Jaeger, Nusbaum, Weismann, and others, based on the results of the labors of morphologists and cytologists, have laid the foundation for a theory of the physical basis of heredity, and

for the supposition that the chromatin in the nucleus of reproductive cells is the bearer of heredity. The theory has already led to prolonged discussions and opened up new lines of work in cytology and embryology.

9. The subject of instinct, discussed both by morphologists and psychologists, particularly by Lloyd Morgan, has come to the front, while mental evolution has been discussed by Romanes and others.

With all these theories before us, these currents and counter currents in evolutional thought bearing us rapidly along, at times perhaps carrying us somewhat out of our depth, the conclusion of the whole matter is that in the present state of zoölogy it will be wise to suspend our judgment on many theoretical matters, to wait for more light, and to confine our attention meanwhile to the observation and registration of facts, to careful experiments, and to repeated tests of mere theoretical assumptions.

Meanwhile we may congratulate ourselves that we have been born and permitted to labor in this nineteenth century, the century which in zoölogical science has given us the best years of Lamarck's life, a Cuvier, a Darwin, a von Baer, an Owen, an Agassiz, a Haeckel, a Spencer, and a Huxley — the founders of modern zoölogy — who have sketched out the grander features of our science so completely that it will, perhaps, be the work of many coming years to fill in the details.

Geological Causes of Variation and of the Extinction and Renewal of Species.

The most immediate and efficient cause of variation appears to be changes of environment or of the physical conditions of existence. These, besides the agencies of gravity, electricity, of the atmosphere, light, heat, cold, food, etc., comprise geological changes or revolutions in the topography of the earth's surface at different periods. The latter causes appear to have had much to do with the process of extinction and renewal of plants and animals.

While the doctrine of the effect on animals of a change of environment was suggested very early in this century and forms the corner stone of Lamarckism, Wallace was, after De la Beche [1] and especially Lyell,[2] the first in recent times, in an essay published in 1855, to call attention to this subject thus:

"To discover," he says, "how the extinct species have from time to time been replaced by new ones down to the very latest geological period, is the most difficult, and at the same time the most interesting problem in the natural history of the earth."[3]

Still more recently [4] he remarks:

"Whenever the physical or organic conditions change, to however small an extent, some corresponding change will be produced in the flora and fauna, since, considering the severe struggle for existence and the complex relations of the various organisms, it is hardly possible that the change should not be beneficial to some species and hurtful to others."

Two conclusions are now generally accepted: the first is, that the most complete evidence of evolution is afforded by paleontology. Huxley's vigorous affirmation that the primary and direct evidence in favor of evolution can be furnished only by paleontology has been greatly strengthened by recent discoveries. The second is, that biological evolution has been primarily dependent on physical and geological changes.

It may not be unprofitable for us as zoölogists to pass in review some of the revolutions in geological history, particularly as regards our own continent, some important details of which have recently been worked out by geologists, and to note the intimate relation between these revolutions and the origination not only of new species but of new faunæ, and indeed, at certain epochs, of new types of organic life.

1. *Precambrian Revolutions.* — That immensely long period which intervened between the time when our planet had cooled down and become fitted for the existence of animal life, and the opening of the Cambrian period, was evidently a time of the geologically rapid production of ordinal and class types of

[1] *Researches in Theoretical Geology*, p. 217. New York, 1837. Quoted by Woodworth, p. 220.

[2] *Principles of Geology*. 1839.

[3] *Natural Selection*, p. 14.

[4] *Darwinism*, p. 115. 1889.

invertebrate life. This is strongly suggested by the fact that a large proportion of the Cambrian classes embrace forms as highly specialized as their successors of the present day, so that we are compelled to look many ages back of the Cambrian for the appearance of their generalized ancestral forms.

Of the eight branches of phyla, of the animal kingdom, the remains of seven, or all except the vertebrates, have been found in Cambrian strata. Adopting the kind of statistics employed by Prof. H. S. Williams in his admirable *Geological Biology*, but with some changes necessitated by a little different view as to the number of classes living at the beginning of the Cambrian period, it appears that 13 out of 26 classes of the animal kingdom, occurring in a fossil condition, already existed in the Cambrian, and, if we throw out from the vertebrate classes those without a solid skeleton (the Enteropneusta or Balanoglossus, Tunicates, Amphioxus, and the lampreys), 13 out of 22. Also, if we exclude the land forms (Arachnida, Myriopoda, and insects), 13 out of 19; and then, throwing out the five vertebrate classes found in a fossil state, of 14 invertebrate marine classes 13 occur in the Cambrian.[1] With little doubt, flatworms, nemerteans, Nematelminthes, and Gephyrea existed then, and probably the representatives of other classes of which no traces will ever occur.

We shall for our present purpose follow the classification of the United States Geological Survey and restrict what was formerly called the Archæan to the fundamental gneiss and crystalline schists of an unknown thickness, and accept the Algonkian, as comprising the Huronian and Keweenawan formations. We may assume that the first beginnings of life took place toward the end of the Archæan, and that the more or less rapid differentiation of class types went on during Algonkian time. This view is fortified by the statement of Walcott that a great orographic movement, followed by long-continued erosion, took place between the Archæan and Algonkian ages.

[1] Should the Polyzoa be traced back to the Cambrian, as it is not at all impossible, the fact would remain that every class of marine invertebrates with solid parts is represented in the Cambrian.

Taking as an example of the nature of the Algonkian changes one region alone, the Lake Superior region, where the stratigraphical record is more complete, we have: —

1. The Lower Huronian schists, limestone, quartzites, conglomerates, etc., with their eruptives, closely folded and attaining a maximum thickness of probably over 5000 feet.

2. The Upper Huronian, unconformable to the Lower, a series of more gently folded schists, slates, quartzites, conglomerates, interbedded and cut by trap, with a maximum thickness of 12,000 feet. In the Animikie quartzites of this age have, according to Selwyn, been detected a track of organic origin, and in the Minnesota quartzites, Lingula-like forms, as well as obscure "trilobitic-looking" impressions; while carbonaceous shales are abundant.

3. Between these Huronian rocks and the true Cambrian series are interpolated the Keweenawan elastic rocks, with a maximum thickness of 50,000 feet. Though these beds are by some high authorities referred to the Cambrian, the fact remains that this series, whether Cambrian or Algonkian, is unconformable to the Huronian, and composed of fragmental rocks, the upper division being 15,000 feet thick, and consisting wholly of detrital material largely derived from the volcanoes of the same series. Between each series is an unconformity representing an interval of time long enough for the land to have been raised above the seas, for the rocks to have been folded and to have lost by erosion thousands of feet, and for the land to have sunk below the surface of the ocean.

Again, between the Precambrian and Cambrian there was, according to Walcott, a great uplift and folding of rock, succeeded by long-sustained erosion, over all the continental area. It was not, however, he states, "as profound as the one preceding Algonkian time, as is proved by the more highly contorted and disturbed Archæan rocks beneath the relatively less disturbed Algonkian series." [1]

The evidence of the existence of life forms in the Huronian and Keweenawan times is indicated by the presence of thick

[1] The North American Continent during Cambrian Time. *Twelfth Ann. Rep. U. S. Geological Survey*, p. 544.

beds of graphitic limestone, beds of iron carbonates, and by a great thickness of carbonaceous shales, which are represented by graphitic schists in the more altered strata. In the Animikie rocks on the northern shores of Lake Superior Ingall finds abundant carbon, and it is said that in certain mines and openings rock gas forms to a considerable extent. Also small quantities of rock may even be obtained which will burn. "These substances must result from the ordinary processes which produce rock gas and coal in the rocks of far later age. The hydrocarbons which occur so abundantly in the slightly metamorphosed shales of the Huronian about Lake Superior must be of organic origin," and if so, the graphitic schists of the same system "are in all probability only these hydrocarbonaceous shales in a more altered condition."

As to the fossils actually detected in what are by some geologists regarded as Algonkian strata, Winchell has detected a Lingula-like shell in the pipestones of Minnesota. Selwyn has described tracks of animals in the Upper Huronian of Lake Superior. Murray, Howley, and Walcott have discovered several low types in the Huronian of Newfoundland, *i.e.*, a mollusk (*Aspidella terranovica*)[1] and traces of a worm (*Arenicolites spiralis*), the latter said to occur in the primordial rocks of Sweden. Walcott reports the discovery in the Grand Cañon of the Colorado of the following Precambrian fossils: "A minute discinoid or patelloid shell, a small Lingula-like shell, a species of Hyolithus, and a fragment of what appears to have been the pleural lobe of the segment of a trilobite belonging to a genus allied to the genus Olenellus, Olenoides, or Paradoxides. There is also an obscure Stromatopora-like form that may not be organic."

Here should be noted the discovery, in 1896, of Radiolaria[2]

[1] Dr. G. F. Matthew writes me as follows regarding this supposed fossil: "I have seen *Aspidella terranovica* in the museum at Ottawa and doubt its organic origin. It seems to me a slickensided mud-concretion striated by pressure. I have found similar objects in the Etcheminian olive-gray beds below the St. John group."

[2] Dr. Matthew likewise writes me: "The (Radiolarian?) rocks of Adelaide, South Australia, Mr. Howchin writes to me he now finds to be Lower Cambrian. He has found Archæocyathus in them; but this is not proof of *Lowest* Cambrian, as the genus is found in the Paradoxides beds of the South of France."

in calcareous and cherty rocks of "undoubted Precambrian age" near Adelaide, Australia (*Nature*, Dec. 24, 1896, p. 192); the detection of fossils in the Archæan of Brittany, and of three veins of anthracite "in crystalline schists of Archæan age" in Ecuador.

At St. John, New Brunswick, that able and experienced geologist, Dr. G. F. Matthew, has detected fossils in strata which he refers to the Upper Laurentian. They occur in three horizons. The lowest series is composed of a quartzite containing fragments of the skeletons of hexactinellid sponges allied to Cyathospongia. In the upper limestone of the second horizon were collected calcareous coral-like structures resembling *Stromatopora rugosa*. In the third and uppermost horizon, consisting of beds of graphite, occurred great numbers of spicules of apparently hexactinellid sponges. "Between this upper Laurentian system and the basal Cambrian occurs," says Matthew, "a third system, the Coldbrook and Coastal, Huronian, which has given conglomerates to the Cambrian and has a great thickness." He also tells us that the Precambrian St. Etcheminian beds at St. John, consisting of red and green slates and shales, have a meager fauna, comprising Protozoa, Brachiopoda, echinoderms, mollusks, with plentiful worm burrows and trails. In commenting on this subject Sir J. W. Dawson remarks that these Etcheminian strata rest on Huronian rocks which, near Hastings, Ontario, contain worm burrows, sponge spicules, "and laminated forms comparable to Cryptozoön and Eozoön." (*Nature*, Oct. 15, 1896, p. 585.)

Even allowing room for error in the correlation of these formations, and in regarding some of these rocks as no older than Cambrian, yet on the whole the result appears to be that abundant vegetation existed in Precambrian times, which was converted into graphite, while representatives of seven classes were perhaps already in existence previous to the Cambrian period.

The following lists give a comparative view of the classes of the periods in question:

Precambrian Classes.	*Cambrian Classes.*
Rhizopoda (Radiolaria).	Rhizopoda (Foraminifera and Radiolaria).
Porifera (Hexactinellid Sponges).	Porifera (Sponges).
	Hydrozoa (Medusæ and Graptolites).
Actinozoa (Corals).	Actinozoa (Corals).
Brachiopoda.	Brachiopoda.
Annelida.	Annelida.
	Crinoidea.
	Asteroidea.
	Lamellibranchiata.
Mollusca.	Gastropoda (including Pteropoda).[1]
	? Cephalopoda (Orthoceras ?).
Trilobita.	Trilobita.
	Crustacea.

It would seem from these data that the physical condition of the sea and atmosphere was favorable to the existence of types for aught we know quite or nearly as highly specialized as those of the same classes now in existence. Life and nature in the Precambrian went on, so far as we can tell, much as in Cambrian times. Though locally there are breaks in the continuity of geological processes, yet probably over the world generally there was a continuity of geological phenomena, and on the whole a tolerably unbroken series of organic forms.

It is obvious, however, that in the regions thus far examined, the Precambrian, whether we include the Archæan or not, more than at any time since, though the land areas are by some considered to be of small extent, was a period of widespread and profound changes in the distribution of land and sea. While it is generally supposed that the extent of the continental areas at the beginning of Paleozoic time was small, forming islands, Walcott is inclined to the belief that it was very considerable, stating:

The continent was larger at the beginning of the Cambrian period than during any epoch of Paleozoic time, and probably not until the development of the great fresh-water lakes of the Lower Mesozoic was there such a broad

[1] Dr. Matthew writes me that he doubts if Hyalithoid shells should be referred to Pteropoda. "Pelsineer quite repudiates them; and to me their heavy shells, and frequent habitat on rough shores, do not speak of the fragile Pteropoda."

expanse of land upon the continental platform between the Atlantic and Pacific oceans. The agencies of erosion were wearing away the surface of this Algonkian continent and its outlying mountain barriers to the eastward and westward, when the epoch of the Lower Cambrian or Olenellus zone began. The continent was not then new. On the contrary, it was approaching the base level of erosion over large portions of its surface. The present Appalachian system of mountains was outlined by a high and broad range, or system of ranges, that extended from the present site of Alabama to Canada, and subparallel ranges formed the margins of basins and straits to the east and northeast of the northern Paleo-Appalachian or the Paleo-Green Mountains, and their northern extension toward the Precambrian shore line of Labrador. The Paleo-Adirondacks joined the main portion of the continent, and the strait between them and the Paleo-Green Mountains opened to the north into the Paleo-St. Lawrence Gulf, and to the south extended far along the western side of the mountains and the eastern margin of the continental mass to the sea that carried the fauna of the Olenellus epoch around to the Paleo-Rocky Mountain trough. (*Loc. cit.*, p. 562.)

Remarking on the habitat, or nature and extent of the sea bottom tenanted by the Olenellus or Lower Cambrian fauna, Walcott remarks:

One of the most important conclusions is that the fauna lived on the eastern and western shores of a continent that, in its general configuration, rudely outlines the North American continent of to-day. Strictly speaking, the fauna did not live upon the outer shore facing the ocean, but on the shores of interior seas, straits, or lagoons that occupied the intervals between the several ridges that rose from the continental platform east and west of the main continental land surface of the time. (*Loc. cit.*, p. 556.)

Dana had previously (1890) claimed that the earth's features, even to many minor details, were defined in Archæan time (evidently referring to all Precambrian time), and that "Archæan conditions exercised a special and even detailed control over future continental growth." May not this idea be extended to include the life of the Precambrian, and may we not suppose that biological variations and evolutions were predetermined, to some degree at least, by the geological conditions of these primeval ages? The continental masses were then foreshadowed by submarine plateaus covered by shallow seas, the deeper portions of the ocean basins not being affected by these oscillations, extensive as they were.

The time which elapsed between the end of the Laurentian and beginning of the Cambrian was immense, or, at least, as long as the entire Paleozoic era. Walcott estimates the length of the Algonkian at 17,500,000 years. This length of time, or even a portion of it, was long enough for the origination and establishment of those classes, whose highly specialized descendants flourished in the Cambrian. Referring to the Precambrian strata Walcott states :

> That the life in the pre-Olenellus seas was large and varied there can be little if any doubt. The few traces known of it prove little of its character, but they prove that life existed in a period far preceding Lower Cambrian time, and they foster the hope that it is only a question of search and favorable conditions to discover it.[1]

Here the imagination of the zoölogist may be allowed for the moment free scope to act. It is perhaps not hazardous to surmise that in the early centuries or millenniums of the Huronian there arose from some aggregated or compound infusorian, the prototype of the sponges.

From some primitive gastrula, which became fixed to the Huronian sea bottom, may have arisen the hydroid ancestor of the Cœlenterates ; owing to its fixed mode of life, the primitive digestive cavity opened upwards, being held in place by the septa, so that the vase-shaped body, growing like a plant, with the light striking upon it from all sides, assumed a radial symmetry. Before the beginning of the Cambrian, for we know Aurelia-like forms abounded on the Cambrian coasts, medusæ budded out from some hydroid polyps, became free swimming, and as a result of their living at the surface became transparent, and thus shielded from the observation of whatever enemies they had, multiplied in great numbers.

From some reptant gastræa there may have sprung, in these primeval times, an initial form with a fore-and-aft, dorso-ventral and bilateral symmetry, which gave origin by divergent lines of specialization to flatworms, nemerteans, and roundworms, as well as Rotifera, and other forms included among the Vermes. It is probable that the trematodes and cestodes, especially the

[1] The Fauna of the Lower Cambrian or Olenellus Zone. *Tenth Ann. Rep. U. S. Geological Survey*, 1888, 1889.

latter, whose organs have undergone such reduction by parasitism, and some of which through disuse have totally disappeared, did not evolve until some time after the appearance of mollusks and fishes.

When existence in these early plastic vermian forms was confined to boring in the mud and silt, the body became cylindrical, as in some nemerteans, and in the threadworms ; some of the latter forms, boring into the mud, became parasites, entering the bodies of other animals which serve as their hosts.

At about this time certain worms, as the simple mechanical result perhaps of threading their way over or through the rough gravelly bottom, became segmented. The establishment of a segmented structure, brought about by the serpentine mode of progression in the direction of least resistance, resulted in the origination of a succession of levers. Following this annulated division of the dermo-muscular tube of worms was the serial or segmental arrangement of the internal organs, *i.e.*, the nervous, excretory, reproductive and glandular, and, in a less degree, the circulatory system.

In certain of these primitive protannelids, as the result perhaps of external stimuli intermittently applied, bristles originated to aid in progression, and finally the segmentally arranged lateral flaps of the skin, the parapodia, which served as swimming organs. Other nepionic forms, at first free swimming, became fixed and protected by two valves, as in the Brachiopoda, which owe their success in Precambrian times to their fixed and protected bodies.

Not long after the annelid type became established, that of the echinoderms apparently diverged from some nepionic worm, like a trochosphere. In such a form there was a tendency to the deposition of particles and plates of lime in the walls of the body, and the type becoming fixed at the bottom, or at least nearly stationary, and meanwhile more or less protected by a calcareous armor, lost its originally bilateral, and acquired a radial symmetry.

But no echinoderms have yet been detected in Precambrian rocks, which, however, have revealed arthropods, as shown by

the traces of a trilobite, and this tends to indicate that radial symmetry is an acquired, not a primitive characteristic.

At this time was solved the problem of the origination of a type of body, and of supports for it either in walking or in swimming, which should fulfill the most varied conditions of life, and this type, the arthropodan, as events proved, was that fitted for walking over the sea bottom, for swimming, or for terrestrial locomotion ; nor was the idea of segmentation both in trunk and limbs discarded when the type culminated in flying forms, — the insects.

The Arthropoda, as the record shows, first represented by trilobites, which structurally are nearer the annelids than Crustacea, was destined to far outnumber in individuals, species, orders, and classes, any other phylum. Fundamentally worm-like or annelid in structure, the body consisted of a linear series of stiff levers, and was supported by limbs segmented in the same way. The variations of the arthropodan theme are greater than in any other groups, and nature, so to speak, succeeded most admirably in this type, with the exception of the Trilobita, which was the first class of the phylum to appear and the first to disappear. The evolution of jointed limbs was accomplished in the most economical and direct way. The parapodia were perhaps utilized, and at first retaining their form in swimming phyllopods, afterwards from being used as supports, became cylindrical and jointed. All this modification of monotypic forms and evolution from them to other types was accomplished not very late perhaps in the Precambrian. After the specialization of the antennæ and of the trunk segments of the trilobites was worked out, all the postantennal appendages being alike, there ensued in some descendant of another vermian ancestor a further differentiation of the postantennal appendages into mandibles, maxillæ, maxillipedes, thoracic ambulatory legs, and abdominal swimming feet, as worked out in the more specialized members of the class of Crustacea.

As soon as the crustacean type became established, the conditions must have been most favorable for its rapid differentiation along quite divergent lines, for in the Cambrian strata occur the remains of four orders, *viz.*, the Cirrhipedia, Ostra-

coda, Phyllopoda, the sole Cambrian form (*Protocaris marshi*) related to the modern Apus, and the Phyllocarida. Of these the barnacles and ostracodes with their multivalve or bivalve carapaces are the most specialized, and in the case of the former the process of modification due to this fixed mode of life must have required ages, as must also the development of that highly modified vermian type, the Brachiopoda.

Indeed, the three lines of descent which resulted in the arthropodan phylum, as it now exists, unless there were three independent phyla, were perhaps initiated before the Cambrian. These lines are : (1) the Trilobita, with their probable successors the merostomes and arachnids ; (2) the Crustacea ; and (3) the myriopods and insects. Of the third line Peripatus or a Peripatus-like form was the earliest ancestor, which of course must have been terrestrial in habits, though its forefather may have been some fresh-water leech-like worm. We venture to state that it is not wholly impossible that so composite a type as Peripatus, which bears at least some of the marks of being a persistent type, took its rise on the continental land of the Precambrian.

In the Precambrian time was also solved the problem by the mollusks of producing a spiral univalve shell ; for while a large proportion of the Gastropoda were protected by patella-like shells of simple primitive conical form, with these coexisted, in the Lowest Cambrian, forms with spiral shells, such as Platyceras and Pleurotomaria. The comparative abundance of those highly modified mollusks, the Pteropoda, in the lowest or Olenellus Cambrian strata, strongly suggests that their divergence from the more generalized gastropod stem, and their adaptation to a surface or pelagic life, must have taken place long anterior to the dawn of the Cambrian.[1] With them must have lived a variety of other surface forms besides Rhizopoda, whose young served as their food. The members of all classes of the Cambrian were carnivorous, feeding on the protoplasm of

[1] Dr. Matthew has discovered at St. John, N. B., a still lower and older bed, containing no Olenellus, but Foraminifera (Orbulina and Globigerina), sponges, Pteropoda, Pelagiella, which was probably an oceanic heteropod, very primitive brachiopods, with Ostracoda and six genera of trilobites.

the bodies of microscopic animals, or on the eggs and young of their own species, some living on the bottom, and others at the surface. Of marine plants of the Cambrian there are but slight traces, and it is evident that what there were were restricted to the coasts and to shallow water. The old idea that plants originally served as the basis of animal life must be discarded. As at present no plant life exists below a few fathoms, a hundred perhaps at the most, and since below these limits the ocean depths are packed with animal life which exists entirely on the young or the adults of weaker forms, so must the rise and progress of animal life have been quite independent of that of plants. The lowest plants and animals may have evolved from some common bit of protoplasm, some protist, but the evolution of the animal types became very soon vastly more complex. The specialization of parts and adaptation to the environment were more thorough and rapid in the lowest animals evidently in consequence of the greater power of locomotion, and aggressiveness in obtaining food from living organisms, and the adaptability of animal life to various oceanic conditions, especially temperature, bathymetrical conditions and a varying sea bottom.

This rapid differentiation and multiplication of different family, ordinal, and class ancestral types went on without those biological checks which operated in later times, when the seas and land masses of the globe became more crowded. There was a comparative absence of competition and selection ; this being due to the lack of predaceous carnivorous forms to produce that balance in nature which afterwards existed. The two most successful and abundant types were the trilobites and brachiopods ; but the former were not especially aggressive in their habits, undoubtedly taking their food in a haphazard way by burrowing in the mud or sand, having much the same kind of appendages and the same feeding habits as Limulus. The brachiopods were fixed or burrowed in the sand, straining the microscopic organisms drawn into the mouth by the currents set up through the action of their ciliated arms. The most destructive and aggressive Cambrian animals known to us were the orthoceratites, but their remains have not yet been

detected below the second Cambrian zone. Even if some protocordate Balanoglossus, ascidians, or even Amphioxus had already begun their existence in these Precambrian times, they could have caused but a little more destruction of life than their contemporaneous invertebrate allies. As the remains of Ostracodermi and sharks have been detected in Trenton strata, perhaps they originated in the Cambrian, when they must have been active forces in the elimination of those Precambrian soft-bodied animals which connected classes now quite wide apart.

The rapid increase in the Precambrian population was hastened by the probable fact that this, more than any subsequent period, was one of rapid migration and colonization. Vast areas of the shallow depths over the site of the embryo continent, more or less shut off from the main ocean by shoals, reefs, and islands, were, by oscillations of the sea bottom and land, opened up at various times to migrants from the older previously settled seas.

The nature of the Precambrian sediments shows that the more open sea bottom was swept by tidal and ocean currents varying in strength and extent. The topography of the ocean bottom over what is now land must have been more diversified than at present. In the late ages of the Algonkian, owing to active competition and the struggle for existence in the overstocked areas, the process of segregation or geographical isolation was rapidly effected, and the migrants from the denser centers of growth pressed into the then uninhabited areas where, as new, vigorous, and prepotent colonists, they broke ground and founded new dynasties.

At such times as these we can easily imagine that, besides the absence of competition, the Lamarckian factors of change of surroundings bringing about new habits and thus inducing new needs, the use and disuse of organs, together with the inheritance of characters acquired during the lifetime of the individual, operated then far more rapidly and in a much more thoroughgoing way than at any period since, while all through this critical, creative period, as soon as there was a sufficient diversity in the incipient forms and structures, a selective principle began to operate.

For forty years past, since the time of Darwin, the idea that these early forms were more rapidly evolved, and that they were more plastic than forms now existing, has constantly cropped out in the writings of our more thoughtful and studious paleontologists and biologists.

Darwin, in his *Origin of Species*, as quoted by Walcott with approval, remarked that it is indisputable that, before the Lowest Cambrian stratum was deposited, long periods elapsed, as long as, or probably far longer than, the whole interval from the Cambrian age to the present day ; and that "during these vast periods the world swarmed with living creatures." Darwin then adds : "It is, however, probable, as Sir William Thompson insists, that the world at a very early period was subjected to more rapid and violent changes in its physical conditions than those now occurring ; and such changes would have tended to induce changes at a corresponding rate in the organism which then existed."

Professor Hyatt,[1] from his exhaustive studies on the Nautiloidea and Ammonoidea, concludes :

> These groups originated suddenly and spread out with great rapidity, and in some cases, as in the Arietidæ of the Lower Lias, are traceable to an origin in one well-defined species, which occurs in close proximity to the whole group in the lowest bed of the same formation. These facts, and the acknowledged sudden appearance of large numbers of all the distinct types of invertebrates in the Paleozoic, and of all the greater number of all existing and fossil types before the expiration of Paleozoic time, speak strongly for the quicker evolution of forms in the Paleozoic, and indicate a general law of evolution. This, we think, can be formulated as follows : *Types are evolved more quickly and exhibit greater structural differences between genetic groups of the same stock while still near the point of origin, than they do subsequently. The variations or differences may take place quickly in the fundamental structural characteristics, and even the embryo may become different when in the earliest period, but subsequently only more superficial structures become subject to great variations.*[2]

If this applies to the evolution of these cephalopods in the Mesozoic, how much more rapidly and efficaciously did the principle operate in the Precambrian period, after the initial

[1] Phylogeny of an Acquired Characteristic. *Proc. Amer. Phil. Soc.*, vol. xxxii, p. 371.

[2] *Geological Biology*, p. 322.

steps in the divergence of types from the unicellular Protozoa took place? The same law of fact obtains with the insects, the eight holometabolous orders having, so far as the evidence goes, originated at nearly the same geological date, near or soon after the close of the Paleozoic era. Williams also shows from a study of the variations of *Atrypa reticularis* that this species in its specific characters shows a greater degree of variability of plasticity in the earlier than in the later stages of its history. We thus conclude that after the simplest protoplasmic organisms originated, the greatest difficulties in organic development, *i.e.*, the origination of the founders of the different classes, were, so to speak, met and overcome in Precambrian times. The period was one of the rapid evolution of types. As Williams[1] has well remarked:

> The chief expansion of any type of organism takes place at a relatively early period in its life-history. Since then, as with the evolution of the continent itself, the farther progressive differentiation of marine invertebrate forms has, since the close of the Precambrian, been a matter of detail.

As well stated by Brooks, since the first establishment of the Cambrian bottom fauna, "evolution has resulted in the elaboration and divergent specialization of the types of structure which were already established, rather than in the production of new types."

In accepting the general truth of this statement and its application to the marine or Cambrian types, it may, however, be modified to some extent. For during the late Paleozoic was witnessed the evolution of the three tracheate, land-inhabiting, air-breathing classes of Arachnida, Myriopoda, and insects, and of the air-breathing vertebrates, with limbs and lungs, comprising the four classes of amphibians, reptiles, birds, and mammals.

2. *The Appalachian Revolution and its Biological Results.*— Unless we except the great changes in physical geography which took place at the end of the Tertiary period, when the mountain chains of each continent assumed the proportions we now see, the Appalachian revolution, or the mountain building and continent making at the close of the Paleozoic age, was

[1] *Loc. cit.*, p. 347.

the most extensive and biologically notable event in geological history. In its effects on life, whether indirect or direct, it was of vastly greater significance than any period since, for contemporaneous with, and as a consequence of, this revolution was the incoming of the new types of higher or terrestrial vertebrates. Through the researches, now so familiar, in the field and study, of the two Rogerses, of Dana, and of Hall, we know that all through the Paleozoic era at least some 30,000 to 40,000 feet of shoal water sediments, both marine and fresh water, derived from the erosion of neighboring lands, were accumulated in a geosynclinal trough over the present site of the range extending from near the mouth of the St. Lawrence to northern Georgia. At the end of the era ensued a series of movements of the earth's crust resulting from the weight of this vast accumulation, which in a geologically brief period sank in, dislocated, and crushed the sides of the trough, and folded the strata into great close parallel folds, besides inducing more or less metamorphism. These folds rising from a plateau formed mountain ranges perhaps as high as the Sierra Nevada or Andean Cordillera of the present day. The plateau emerged above the surface of the Paleozoic ocean, and was carved and eroded into mountain peaks, separated by valleys of erosion, the rivers of the Appalachian drainage system cutting their channels across the mountain ranges.

But this process of mountain building and erosion was not confined to the end of the Paleozoic era. Willis[1] has shown that there have been several successive cycles of denudation, covering a period extending from the end of the Paleozoic era to the present time. And it is the fact of these successive cycles of denudation both on the Atlantic and Pacific slopes of our continent that is of high significance to the zoölogist from the obvious bearings of these revolutions on the production of variations. Indeed it is these phenomena which have suggested the subject of this address.

We can imagine that this great plateau, in the beginning of the Mesozoic era, with its lofty mountain ranges and peaks rising from the shores of the Atlantic, presented different

[1] *National Geographical Magazine*, vol. i (1889), pp. 291–300.

climatic zones, from tropical lowlands with their vast swamps, to temperate uplands, stretching up perhaps to Alpine summits, with possibly glaciers of limited extent filling the upper parts of the mountain valleys. New Zealand at the present day has a subtropical belt of tree ferns, while the mountains bear glaciers on their summits; and in Mexico, only about 20° from the tropics, rising above the tropical belt, is the temperate plateau, and farther up the subalpine snow-clad summits of Popocatepetl, Orizaba, and other lofty peaks. So in the Appalachians of the Paleozoic, the cryptogamous forests and their animal life may have been confined to the coastal plains and lowlands, while on the higher, cooler levels may have existed a different assemblage of life; and it is not beyond the reach of possibility that a scanty subalpine flora peopled the cooler summits.

But the unceasing process of atmospheric erosion and river action continued through the Jurassic, which was, as stated by Scott in his *Introduction to Geology*, "a time of great denudation, when the high ranges of the Appalachian Mountains were much wasted away, and the newly upheaved, tilted, and faulted beds of the Trias were deeply eroded." At about the time of the opening of the Cretaceous the range was reduced to a peneplain (the Cretaceous peneplain), with only vestiges of once lofty mountains, the scenic features roughly recalling those of North Carolina and New England at present, although more subdued and featureless, more like the Kittatinny peneplain of the Piedmont district at the eastern base of the Blue Ridge to-day as contrasted with the present mountain region of Pennsylvania and New Jersey. There were also extensive changes in the interior. What was the Colorado island was added to the mainland, and a great Mediterranean sea extended from the Uinta Mountains of southeastern Wyoming to New Mexico and Arizona, and stretched from the Colorado peninsula westward to Utah. In the Upper Jurassic as the result of a depression a gulf was formed over northern Utah, Wyoming, and southern Montana (Scott).

The formation of this Cretaceous peneplain was succeeded by a reëlevation, and the surface which is now Virginia was

gradually raised to a height of 1400 feet, and again the sluggish rivers of the Cretaceous times were revivified, cutting through the harder strata forming the walls of the longitudinal valleys, and, widening into broad estuaries, emptied into the Atlantic.

In the Eocene Tertiary, as Willis tells us, "the swelling of the Appalachian dome began again. It rose 200 feet in New Jersey, 600 feet in Pennsylvania, 1700 feet in southern Virginia, and thence southward sloped to the Gulf of Mexico." In consequence of the renewed elevation, the streams were revived; and Willis adds: "Once more falling swiftly they have sawed and are sawing, their channels down, and are preparing for the development of a future base-level." [1]

We can in imagination see, as the result of these widespread physical changes, inducing as they must have done the formation of separate basins or areas enclosed by mountain ranges, with different climates and zones on land, however uniform might have been the general temperature of the world at that time and the other physical conditions of the sea,—we can imagine the profound and deep-seated influence thus exerted on the life-forms peopling the uneven surface of the land.

The vegetation of the lowlands was rich and luxuriant, as the Triassic (Newark) coal deposits near Richmond testify, and while the uplands and hills were probably clad with dense forests of conifers, on the drier desert areas of the peneplain the trees may have been more scanty, like the scattered pines of the drier elevated region of the southwest, and of the Great Basin at the present day. The distribution of the animal life must have corresponded; one assemblage, especially the amphibians, characterizing the hot and humid lowlands, another the cooler uplands, while already perhaps a few forms became adapted to the more arid desert areas, as is the case now in Australia, which is in a sense a Mesozoic continent.

Similar subsidences and elevations changed the Jurassic map in Eurasia. This continent was already a land mass of great extent, and fresh-water lakes extended across Siberia, and in China were extensive swamps and submerged lands, now repre-

[1] Quoted from Scott's *Introduction to Geology*, p. 342.

sented by coal fields. Afterwards in the Middle Jura this continent subsided, and the Jurassic sea covered the greater part of Europe and Asia, this being, according to Neumayr, "one of the greatest transgressions of the sea in all recorded geological history." Subsidences and elevations resulted, it is supposed, in cutting off India from Eurasia so that the strait or sea covered the site of the Himalayas, and India was possibly joined to Australia, the Malaysian peninsula forming the connecting link; or perhaps it stretched to the southwestward and was joined to South Africa. However this may be, it is sufficient for our present purpose that these vast changes in the relative position of land and sea were productive of a corresponding amount of variation, and perhaps of immigration and consequent isolation. At all events, throughout the Jurassic seas as a whole there seemed to have been remarkable faunal differences. This led Neumayr, in which he is followed by Kayser,[1] to conceive that there were already in Jurassic times climatic zones, corresponding to the boreal, polar, north and south temperate, and tropical zones of the present day. If, however, with Scott, we reject this view, and substitute for it the supposition that "the marked faunal differences are due to varying facies, depth of water, character of bottom, etc., and even more to the partly isolated sea basins and the changing connections which were established between them," it is of nearly the same import to the geological biologist, for these varying conditions of the Jurassic ocean bottom could not have been without their influence in causing variation, modification, and adaptation to this or that set of conditions of existence.

Turning now to the effects of the Appalachian revolution on the life of that time, we see that the biological results were, in the main, in conformity with the geological changes. During the Carboniferous period vertebrates with limbs and lungs appeared, *i.e.*, the labyrinthodonts or Stegocephala. They were, compared with the other orders of their class, the most composite and highly organized of the Amphibia.

Throughout the long period of comparative geological quiet,

[1] *Text-Book of Comparative Geology*, translated and edited by Philip Lake, pp. 270, 271.

those long ages of preparation which ended in the crisis or cataclysm which closed the Paleozoic, the amphibian type was slowly being evolved in the swamps and bayous of the lowlands of the Devonian, whose vegetation so nearly anticipated that of the Carboniferous, from some Devonian [1] or late Silurian ganoids, from which diverged on the one hand Dipterus and the colossal lungfish (Dinichthys and Titanichthys) of the Devonian, and perhaps on the other the labyrinthodonts, which may have sprung from some crossopterygian fish like Polypterus, and whose pectoral and ventral fins became adapted for terrestrial locomotion. The type evidently was brought into being, provoked by, and at the same time favored by, the great extent of low coastal swampy land and bodies of fresh water which bordered the Atlantic seaboard from the Silurian time on.

How the amphibian type arose from the ganoid stock is a matter of conjecture. It may, however, be surmised that certain of the lungfishes or forms like them, adapted for breathing the air direct when out of the water in the dry season, instead of remaining in their mud cells waiting for the rains to fill the lakes or swell the rivers, attempted, like the Anabas, or climbing fish, to migrate in schools overland; or, like that fish which is said to have become "so thoroughly a land animal that it is drowned if immersed in water," [2] it may have become confined to the land, and, losing its gills, used its lungs only. As the final result of its efforts to walk over the damp soil and mud of swampy regions, the uniaxial fins may have developed, through the strains and pressures of supporting the clumsy body, into props with several leverage systems; the basalia instead of remaining in one place, as in a fish's fin, spreading out and becoming digits to support the weight and steady the body while walking. This process was not confined to one or to a few individuals, but, as Lamarck insists in the cases he mentions, it affected all the individuals over a large area. Those individuals with incipient limbs became erased or

[1] Certain footprints recently discovered in the Upper Devonian show that the type had become established then, at least vertebrates with legs and toes.

[2] Parker and Haswell's *Text-Book of Zoölogy*, vol. ii, p. 220.

swamped, and we find no trace of them in the strata yet examined.

Thus far, indeed, paleontology is silent [1] as to the mode of origin of the amphibian limb, as it is concerning the origin of arthropod limbs from the parapodfa of annelids. Unfortunately, and this is still a weak point in the evolution theory, nowhere do we find, unless we except the Archæopteryx, clear examples of any intermediate forms between one class and another; each species, as far as its fossil remains indicate, seems adapted to its environment.

There are numerous cases of vestigial structures, but no rudimentary ones showing distinct progressive steps in a change of function. Hence arises the very reasonable view held by some that nature may make leaps, and that new adaptations or organs may be suddenly produced. No inadapted plant or animal as an entire organism has ever been observed either among fossils or existing species. Man has some seventy vestigial structures, but his body as a whole, notwithstanding the disadvantages of certain useless vestiges, is in adaptation to his physical and mental needs.

While the true Carboniferous labyrinthodonts were few and generalized, with gills and four legs, already in the Permian, where we meet with some thirty forms in the Ohio beds alone, and about as many in Bohemia, a great modification and specialization had taken place. Forms like Peleon and Branchiosaurus had gills and four legs; others were like our lizards, as in Keraterpeton; Dendrerpeton and Hylonomus of Nova Scotia were more lizard-like and with scales; others, perhaps, swam by means of paddles, as in Archegosaurus; others, like the "Congo snake," were snake-like, with small, weak legs, as Œstocephalus; some had gills but no legs, as in Dolichosoma, while in others the limbless body was snake-like and scarcely

[1] Paleontology is also equally silent as to the origin of pleisosaurs and ichthyosaurs from their terrestrial digitigrade forbears; though in Archæopteryx we have an unusually suggestive combination of reptilian and avian features. Certain Theriodontia point with considerable certainty to the incoming of mammals such as the Echidna and duckbill, but as to the steps which led to the origin of brachiopods, echinoderms, trilobites, of Sirenians and of whales, paleontology affords no indications.

larger than earthworms, as in Phlegethontia of the Ohio and Ophiderpeton of the Bohemian coal measures.

Already, then, in Permian times the stegocephalous type showed signs of long occupation, old age, and degeneration. The process of degeneration and reduction in, and loss of, limbs may have been initiated as far back as the closing centuries of the Devonian.

The effect of the Appalachian revolution and corresponding physical changes in Europe was by no means disastrous to the Stegocephala, for those of the Liassic, where the conditions must have been more formidable to terrestrial vertebrate life, were abundant, and in some cases at least colossal in size. Whether the salamanders, cœcilians, sirens, and Amphiuma of present times are persistent types, survivors of Carboniferous times, or whether the process of modification has been accomplished a second time within the limits of the same class, is, perhaps, a matter for discussion.

Besides the introduction and elaboration of the air-breathing, four-footed labyrinthodonts, the sloughs and sluggish streams were alive with Naiadites and its allies, forerunners of the Unionidæ, and with them lived shelled phyllopods, Estheria having already appeared in the Devonian, Leaia appearing in the Carboniferous; and also the larvæ of aquatic net-veined insects, fragments of the imagines of which were detected by Hartt at St. John, New Brunswick.

The coal-bearing strata are largely fresh-water beds of fine shale, and well calculated to preserve the hard parts of delicate animals, but on general grounds it is evident that the great extent of lowlands with extensive bodies of fresh water communicating with the shallow sea was most favorable to the development and differentiation of terrestrial life. Though fresh-water and land shells (pulmonates) appeared in the Devonian, they were apparently more abundant in the coal period. Especially rapid was the incoming of the arthropods; both diplopods, some of them very remarkable forms, and chilopods lived sheltered under the bark of colossal lycopods; with them were associated scorpions, harvestmen, and spiders. The great profusion of net-veined insects discovered at Com-

mentry, France, shows that this was the age of the lower, more generalized, or heterometabolous insects, such as cockroaches, and other Orthoptera, of Eugereon, may-flies, and possibly dragon flies, etc., our wingless stick insects being then represented by winged ancestors. At this time also began the existence of insects with a complete metamorphosis, as traces of true Neuroptera and the elytra of a beetle have been detected in Europe. But thus far no relics of flowers or of the insects which visit them have been discovered in Carboniferous times, not even in the Permian, so that the origin of insects with a complete metamorphosis, such as moths, ants, and flies, may be attributed to the new order of things, geographical and biological, immediately following the Appalachian revolution.

We do not wish to be understood as implying that the origin of new orders and classes is directly due to geological crises or cataclysms themselves.[1] On the contrary, the initial steps seem to have been taken as the result of the gradual extension of the land masses, and the opening up of new areas; it was the period of long preparation, with long-continued oscillations, the slowly induced changes resulting from the reduction of the mountainous slopes to peneplains, which were most favorable to the gradual modification of forms resulting in new types, the gradual process of extinction of useless and senile forms, and the modification and renewal of those which became adapted to the new geographical conditions.

It should be borne in mind that this extension of the low coasts of the continents began in Ordovician times, but the remarkable expansion of our continent after the Appalachian

[1] I find that Wood has already expressed the same idea more fully, as follows: "Both in the Paleozoic and Secondary periods, therefore, the complete changes in the fauna which marked their termination do not appear to have been immediate upon the changes of the geographical alignment, but to have required the lapse of an epoch for their fulfillment; and the completeness of that change is perhaps not less the indirect result of the altered alignment, by the formation of continents where seas had been, and the opening out of new seas for the habitation of marine animals, thereby causing a gap in the geological records so far as they have been hitherto discovered, than the direct result of the changed conditions to which the inhabitants of the seas, and even those of the land, came to be subject on account of the entire change in the alignment of the land over the globe." (*Phil. Mag.*, vol. xxiii, 1862, p. 281.)

revolution, rather than the upheaval of the plateau itself, so favorably affected plant and animal life that at the dawn of the Mesozoic a great acceleration in the process of type-building was witnessed. Moreover, it seems evident that the variation which took place at this epoch was by no means fortuitous, but determined along definite lines caused by the definite expansion of the continents, and their resultant topography.

We have seen that as a result of the folding and upheaval of the Appalachians there may have been at the beginning of Triassic time, in addition to the tropical lowlands, a somewhat cooler upland zone, and possibly even snow-clad mountain peaks, with glaciers descending their sides, as we may now witness in New Zealand.

Already on Permian soil reptiles were not infrequent. They were generalized composite forms comprising the Proganosauria, the forerunners of the Hatteria of New Zealand, and the Theriodontia, from which the mammals are now supposed to have been derived. They disappeared at the end of the Triassic, together with the labyrinthodonts, from which the reptiles are thought to have originated. These reptiles having scaly bodies and claws, their habits must have been like those of the lizards of to-day, and they were adapted for hotter and drier, perhaps more elevated, areas than the stegocephalous amphibians ; and these conditions were fulfilled in Triassic and Jurassic times, when the reptilian orders multiplied, all the orders of the class having been differentiated, or at least were in existence, in the Mesozoic era.

The geographical features throughout the Mesozoic were these : more or less dry and broad plains, vast fresh-water lakes, uplands clad with coniferous forests afterwards to be replaced by forests of deciduous trees ; flower-strewn plains overgrown with waving grasses, and jungles with rank growths of bamboo. We can, without going into detail, well imagine that the geographical features of the Mesozoic continents were such as to provoke the appearance of the higher classes of vertebrates. As the land rose higher and the low swampy coastal areas became more limited, this would tend to restrict the habitat of the stegocephalous amphibians ; with a slightly

more elevated and drier coast, the incoming and expansion of reptilian life were fostered ; with still higher plains and hills, besides the increasing abundance of flowers and other seed-bearing plants and of the insects which visit them, existence for birds became possible, and with them that of a few scattered mammals of small size and generalized structure, with similar insectivorous habits.

During the age of reptiles, when they swarmed in every jungle, throughout the forests and over the plains, competition rose so high that some of them were forced to take flight, and bat-like, provided with membranous wings, the pterodactyls lived in a medium before untried by any vertebrate, and finally there appeared in the Ornithostoma of the Cretaceous a colossal flying reptile, its wings spreading twice as much as any known bird, with a head four feet in length, its long toothless jaws closing on swarms of insects or perhaps small fry of its own type. But the experiment, in point of numbers or capacity for extended flight, did not succeed. Another type assayed the problem with better success. There appeared feathered and eventually toothless vertebrates, with the fore extremities converted into pinions and the hinder ones retaining the raptorial reptilian form better adapted for aërial life. They eked out a by no means precarious existence on flying insects and seeds, as well as on the life in the soil or by the seaside, and rapidly replaced certain older reptilian types. The class of birds has become about four times as numerous as the reptiles, and outnumbers the mammals nearly six times.

We may now review the zoölogical changes which took place at the time including the end of the Paleozoic and the opening of the Mesozoic. There was an extinction of the Tetracoralla and their replacement by corals with septa arranged in sixes ; an extinction of cystidian and blastoic crinoids, the dying out of old-fashioned crinoids and echinoids (Palæocrinoidea and Palæechinoidea), followed by the rise of their more modern specialized successors. As rapidly as the brachiopods became diminished in numbers, their place at the sea bottom was taken by the more active and in some cases predatory bivalve and univalve mollusks. As the trilobites became extinct, their

place in part was filled by their probable descendants, the Limuli, which had already begun to appear, the earliest types being Neolimulus, Exapinurus, and other forms of the Silurian, and Protolimulus of the Devonian. The Limuli of the Carboniferous, some with short (Prestwichia and Euproöps) and others with long tail spines (Belinurus), suggest long possession of the soil and consequent variation and differentiation.

The Eurypterida shared the fate of the trilobites, and while there was a thorough weeding out of the more typical ganoids, leaving an impoverished assemblage to live on through after ages, that singular primitive vertebrate group, the Ostracodermi, was wholly obliterated.

On the other hand, with the incoming of a new order of vegetation a great outgrowth of winged insects, the representatives of the orders of Lepidoptera and Hymenoptera, now so numerous in species, began their existence.

By the close of the Appalachian revolution, probably all the orders of insects had originated, unless we except the most modified of all, the Diptera, whose remains have not been detected below the Lias. With but little doubt, however, the eight orders of holometabolous insects diverged in the Permian, if not near the close of the Carboniferous, from some protoneuropter, the progress in the differentiation of genera and families becoming rapid either during the Jurassic or directly after the lower Cretaceous, or as soon as grasses and deciduous trees became in any way abundant.

Very soon, too, after the close of the revolution, the ancestral birds and mammals diverged from the reptiles, and of the latter the turtles, plesiosaurs, ichthyosaurs, crocodiles, and dinosaurians, and soon after the pterodactyles, came into existence.

As a result of this revolution the molluscan type was profoundly affected, as, at the opening of the Triassic, siphoniate Pelecypoda, opisthobranchiate Gastropoda, and cuttles or belemnites appeared. While a few orthoceratites lingered on after the revolution, the ammonites blossomed out in an astonishing variety of specific and generic forms.

In summing up the grand results of the Appalachian revolution and of the times immediately succeeding, we should not

lose sight of the fact that the changes in the earth's population were due not less to biological than to geological and topographical factors. The process of extinction was favored and hastened by the incoming of more specialized forms, many of them being carnivorous and destructive; as, for example, nearly all fishes and reptiles live on other animals. The struggle for existence between those which became inadapted and useless in the new order of things went on more actively than at present. The process of extinction of the higher, more composite amphibians (the labyrinthodonts) was largely completed by the multitude of theromorphs and dinosaurs which overcame the colossal Cheirotherium, Mastodonsaurus, and their allies.[1]

During the centuries of the Trias the lowlands became crowded, and the reptilian life was forced in some cases to gain a livelihood from the sea, for at this time was effected the change from small terrestrial reptiles like Nothosaurus to the colossal plesiosaurs and ichthyosaurs, in which digitate limbs were converted into paddles; and the ocean, before this time uninhabited by animals larger than ammonites, cuttles, and sharks, began to swarm with colossal vertebrates, the increased volume of their new and untried habitat resulting in a tendency to a corresponding increase in weight, just as whales, which possibly evolved from some land carnivore in the early Tertiary, waxed great in bulk, the increase in size perhaps having been due to the great volume of their habitat, the ocean.

Nothing so well illustrates the advantage to an incipient type as entering a previously uninhabited topographical area, or a new medium, such as the air, in the case of the pterodactyles, the first vertebrates to solve the problem of aërial flight. Originating and prospering in the early Mesozoic, they held

[1] After writing the above lines I find the same view expressed in Woodworth's *Base-Levelling and Organic Evolution.* He remarks: "The exact cause of their decline is probably to be sought in the development of the more powerful reptilia" (p. 225). Regarding the circumstances favorable to reptilian life, he also states: "In the development of the peneplain from the high relief of the Permian and again at the close of the Jura-Trias, the widening out of the lowland, with plains and jungles, near tide-level, followed by depression of the land, must have highly favored the water-loving reptilia. It is to these geographical circumstances, I think, that we must look for our explanation of the remarkable history of this class in Mesozoic times" (p. 226).

their own through the Cretaceous, where at their decline they became, as in Ornithostoma, colossal and toothless. We can imagine that the demise of this type was assisted in two ways: those with a feebler flight succumbed to the agile, tree-climbing dinosaurs; while the avian type, waxing stronger in numbers and power of flight and exceeding in intelligence, exhausted the food supply of volant insects, and drove their clumsier reptilian cousins to the wall, fairly starving them out; just as at the present day the birds give the bats scarcely a *raison d'être*.

3. *The Pacific Coast Revolutions.* — It has long been known that there are a greater number of insect faunæ on the Pacific coast, and greater variation of species, with more local varieties, than east of the Mississippi River. It has also been shown by Gilbert and Evermann, as well as by Eigenmann, to apply to the fishes of the Columbia and Frazer River basins. "Nowhere else in North America," says the latter, "do we find, within a limited region, such extensive variations among fresh-water fishes as on the Pacific slope." He also points out the noteworthy fact that the fauna is new as compared with the Atlantic slope fauna, and "has not yet reached a stage of stable equilibrium." As previously shown by Gilbert and Evermann, "each locality has a variety which, in the aggregate, is different from the variety of every other locality"; and he adds: "the climatic, altitudinal, and geological differences in the different streams, and even in the length of the same stream, are very great on the Pacific slope."

It is evident that the variations are primarily due to the broken nature of the Pacific coast region, and to the isolation of the animals in distinct basins more or less surrounded by high mountain barriers, with different zones of temperature and varying degrees of humidity.

As brought out by the labors of Le Conte, Diller, and Lindgren, the Sierra Nevada region has undergone cycles of denudation, and these changes, occurring later than those of the Appalachian region, have doubtless had much to do with the present diversified and variable fauna. The latest writer, N. F. Drake,[1] states that the western slope of the Sierra Nevada

[1] The Topography of California. *Journ. of Geol.*, vol. v (September and October, 1897), pp. 563–578.

"was probably once a region worn down almost to base-level or to a peneplain. By the uplift of the mountains a great fault was developed along the eastern face, and the whole Sierra crust-block tilted to the westward. The streams quickened by the uplift again set to work on the peneplain and carried it to its present condition."

Le Conte[1] states that the Sierra Nevada was upheaved at the end of the Jurassic period. This corresponded to the Appalachian revolution, which occurred at the end of the Paleozoic era.

> But during the long ages of the Cretaceous and Tertiary this range was cut down to very moderate height. . . . The rivers by long work had finally reached their base-levels and rested. The scenery had assumed all the features of an old topography, with its gently flowing curves. . . . At the end of the Tertiary came the great lava streams running down the river channels and displacing the rivers; the heaving up of the Sierra crust-block on its eastern side, forming the great fault-cliff there and transferring the crest to the extreme eastern margin; the great increase of the western slope and the consequent rejuvenescence of the vital energy of the rivers; the consequent down-cutting of these to form the present deep canyons and the resulting wild, almost savage, scenery of these mountains.

This view is further carried out by J. S. Diller, from his studies of the northern part of the Sierra Nevada, including the borders of the Sacramento Valley and the Klamath Mountains. He shows that northern California, during the earlier portion of the auriferous gravel period, was by long-continued degradation worn down to base-level conditions. "The mountain ranges," he says, "were low, and the scenery was everywhere characterized by gently flowing slopes. . . ."

"The topographic revolution consisted in the development out of such conditions of the conspicuous mountain ranges of to-day. The northern end of the Sierra Nevada has since been raised at least 4000 feet, and possibly as much as 7000 feet, and a fault of over 3000 feet developed along the eastern face of that portion of the range."[2]

According to Lindgren, the Sierra Nevada was eroded to, or almost to, a peneplain during Cretaceous times, and the moun-

[1] *Bull. Geol. Soc. Amer.*, vol. ii, pp. 327, 328.
[2] *Fourteenth Ann. Rep. U. S. Geol. Survey*, Pt. ii, p. 433.

tains elevated in a later Cretaceous period were worn down during Tertiary times merely to a gentle topography.

The other post-Cretaceous changes of this vast region are thus summarized by Scott from the results of Pacific coast geologists: in the Eocene a long narrow bay occupied the great valley of California extending northward into Oregon and Washington. At the end of the Eocene or early in the Miocene an elevation in California shifted the shore line far to the west. In the Miocene the Coast range formed a chain of reefs and islands, and at the close an upturning and elevation of the mountain range took place, though it became higher afterwards. The Coast range sank again early in the Pliocene, and the San Francisco peninsula was an area of subsidence and maximum deposition forming the thickest mass (58,000 feet) of Pliocene in North America. The mountains of British Columbia are believed to have been at a higher level than now, as it is supposed that Vancouver and Queen Charlotte Islands probably formed part of the mainland.

At or near the close of the Pliocene the Sierra Nevada increased in height by the tilting of the whole block westward. New river valleys, cut through the late basalt sheets of the Sierras, are much deeper than the older valleys excavated in Cretaceous and Tertiary times, owing to the greater height of the mountains and to the consequent greater fall of the streams. At this time the Wasatch Mountains and high plateaus of Utah and Arizona were again upraised, and the great mountain barrier of the St. Elias in southeastern Alaska was likewise thrown up. At this time also, or perhaps later, the mountains of British Columbia were probably raised still higher.[1] It will be seen from this that the present topography of the western border of our continent, including Central America and the Isthmus of Panama, belongs to a new topographic era, and fully substantiates the view that the fauna of these regions is very recent compared with that of the Atlantic border, and that the number of nascent or incipient species is much greater.

4. *The Upper Cretaceous Revolution.* — Another profound and epoch-making change occurred at the beginning of the Upper

[1] *Journ. Geol.*, vol. iv, pp. 882, 894, 897, 898. (Quoted from Drake.)

Cretaceous. In Eurasia, as Kayser states, "this was one of the greatest changes in the distribution of land and water over almost the whole earth, that is known in geographical history. Extensive areas which had for long periods been continents were now overflowed by the sea and covered with Cretaceous deposits"; the Upper Cretaceous strata in certain areas in Germany and Belgium resting directly on Archæan rocks. In America (the Dakota stage) there was also a great subsidence. The Atlantic coastal plain was submerged over what was Triassic soil, also the lowlands from New Jersey through Maryland to Florida, while the Gulf of Mexico extended northward and covered western Tennessee, Kentucky, and southern Illinois; a wide sea connected the Gulf of Mexico with the Arctic Ocean, and thus the North America of that time was divided into a Pacific and an Atlantic land, the latter comprising the Precambrian and Paleozoic areas.

As Scott states: "The Appalachian Mountains, which had been subjected to the long-continued denudation of Triassic, Jurassic, and Lower Cretaceous times, were now reduced nearly to base-level, the Kittatinny plain of geographers. The peneplain was low and flat, covering the whole Appalachian region, and the only high hills upon it were the mountains of western North Carolina, then much lower than now. Across this low plain the Delaware, Susquehanna, and Potomac must have held very much their present courses, meandering through alluvial flats" (p. 481). An elevatory movement began in the succeeding or Colorado epoch, and this was succeeded by an uplift on the Atlantic and Gulf coasts, and the continued upheaval in the interior resulted in the deposition of the Laramie brackish and fresh-water beds. There were similar widespread subsidences and upheavals in South America, the Andean chain being in large part upheaved at the close of the Cretaceous.

In the Cretaceous period there were such differences in the distribution of the fossils as to lead Römer, from his explorations in Texas as early as 1852, to consider that the resemblance of the fossils of Texas, Alabama, and Mexico, with the West Indies and Columbia, to those of southern Europe, were

due to differences of climate, a view reiterated by Kayser (p. 283). Scott also states that the Lower Cretaceous beds of Texas show faunal resemblances which ally them to the Portugal and Mediterranean beds, while the faunal relations of South American Lower Cretaceous strata are closely like those of northern and western Africa.

The biological changes at the beginning of the Upper Cretaceous were correspondingly notable. Vast forests of conifers, palms, and especially of deciduous trees, such as the oak, sassafras, poplar, willow, maple, elm, beech, chestnut, and many others, clothed the uplands, while in the jungles, on the plains, and in the openings of the forests, gay flowers bloomed. The flora must even then have been, comparatively speaking, one of long existence, because highly differentiated composite plants, like the sunflower, occur in the Upper Cretaceous or Raritan clays of the New Jersey coast. It may be imagined that with this great advance in the vegetables, the higher flower-visiting insects must have correspondingly multiplied in number and variety.

While the changes of level did not affect the abysses of the sea, the topography of the shallows and coast was materially modified, and to this was perhaps largely due the extinction of the ammonites and their allies.[1] It is not impossible that the

[1] After preparing this address, I find that Wood thirty-six years ago more fully discussed this matter, and mentions the same cause we have suggested. "This disappearance," he says, "of the Ammonitidæ, and preservation of the Nautilidæ, we may infer was due to the entire change which took place in the condition of the shores at the close of the Cretaceous period; and this change was so complete that such of the shore followers as were unable to adapt themselves to it succumbed, while the others that adapted themselves to the change altered their specific characters altogether. The Nautilidæ having come into existence long prior to the introduction of the Ammonitidæ, and having also survived the destruction of the latter family, must have possessed in a remarkable degree a power of adapting themselves to altered conditions." On the other hand, the dibranchiate cephalopods (cuttles or squids), living in deeper water, being "ocean-rangers," were quite independent of such geographical changes. Wood then goes on to say that the disappearance of the tetrabranchiate group affords a clew to that of the Mesozoic saurians, and also of cestraciont sharks, whose food probably consisted mainly of the tetrabranchiate cephalopods. "Now the disappearance of the Tetrabranchiata, of the cestracionts, and of the marine saurians, was contemporaneous; and we can hardly refuse to admit that such a triple destruction must have arisen either from some common cause or from these forms being succes-

uncoiling of the ammonites into forms like Scaphites, Crioceras, Helioceras, Turrilites, and Baculites, were originally perhaps distortions due to physical causes somewhat similar to those which produced a loosening or uncoiling of the spire in Planorbis. These variations or distortions of the pond snail, signs of weakness, the result either of pathological conditions or of senility, were due to unfavorable changes in the environment, such as either a freshening of the water or some other chemical alteration in the relative amount of alkalines and salts. The changes in the ammonites, though more remarkable, are similar to the aberrations observable in the shells of the upper and later layers of the Steinheim deposits, made known to us by Hilgendorf, Sandberger, and more especially by the detailed and masterly researches of Professor Hyatt.

In this case the Miocene Tertiary *Planorbis lævis* was supposed to have been carried into a new lake, before untenanted by these shells. Although from some unknown cause the lake was unfavorable to the production of normal *lævis*, whose descendants show the results of accidents and disease, yet, owing to isolation, which prevented intercrossing with the present stock, and to the freedom from competition, the species was very prolific, and the lake became stocked with a multitude of more or less aberrant forms constituting new species. Some of them are nearly normal, with a flat spire, others are trochiform, and others entirely unwound or corkscrew-shaped. Similar aberrations occur in *Planorbis complanatus*, living in certain ponds in Belgium (Magnon) ; in the slightly twisted planorbid *Helisoma pexata* Ingersoll of St. Mary's Lake, Antelope Park, Colorado, and in the unwound forms of Valvata first found by Hartt in Lawlor's Lake near St. John, New Brunswick, and described by Hyatt.[1] In all these cases of parallelism or convergence the aberrations seem to have been due to some unusual condition of the water adverse to normal growth. Hence, it is not impossible that the singular uncoiled or

sively dependent for existence upon each other." He also suggests that the development of the cuttles "has been commensurate with that of the cetacean order, of some of which they form the food." (*Phil. Mag.*, vol. xxiii, 1862, p. 384.)

[1] *Ann. Rep. Hayden's U. S. Geol. and Geog. Survey Territories.*

straight forms assumed by certain of the ammonites when on the verge of extinction were likewise cases of convergence, and due to weakness or senility, or at least to an unusual and unfavorable condition of the seas in which they lived.

The physical causes of extinction of the Mesozoic reptiles may also have been due to, or connected with, the changes of coast level, although signs of weakness and senility are exhibited by these. In the Como or Atlantosaurus beds referred by Scott to the Lower Cretaceous rather than Jurassic, the ichthyosaur (*Sauranodon natans*) was toothless, while the colossal Cretaceous pterodactyle Ornithostoma (Pteranodon) was entirely toothless.

The colossal Pythonomorpha, offshoots of terrestrial lizards, but with paddles adapting them for marine existence, succeeded the plesiosaurs, and may have materially aided in their extinction. Hence arises the question, Did the extinction of the marine reptiles result in, or contribute to, the great increase of teleost fishes?

Before the dinosaurs began to die out, the type in part became specialized into lizard-like, tree-climbing forms, and agile, bird-like forms. The first birds of the Cretaceous were toothed, carinate, highly predaceous forms, with a retrogressive side branch of wingless diving birds, represented by the colossal Hesperornis, but in this case the loss of teeth was undoubtedly a gain to the type, compensation for the lack of a dental armature in the seed-eating birds being shown in the elaboration of a gizzard.

5. *Geological Changes in the Tertiary.* — Here again we have, as in former periods, a succession of earth movements, subsidences in one region and elevations in another, though apparently more limited in extent than before, the oscillatory movements being rather confined to coastal areas, and involving adjacent shallow seas, there being frequent alternations of marine with brackish and fresh-water beds. As Kayser remarks, the Tertiary deposits "no longer extended unaltered over whole countries like those of older systems, but generally occupied only smaller basin or bay-like areas, filled-up inland seas or shallow gulfs" (p. 328). Towards the close of the

Tertiary the great mountain ranges of Asia and Europe, the Alps, Pyrenees, Caucasus, Himalayas, as well as the Atlas, and the Cordillera of North and South America were upheaved. The old Tertiary nummulitic beds were, in the western Alps, raised to a height of 11,000 feet, and the Himalayas to a horizon 16,000 feet above the sea, while there were corresponding elevations in western North America and in the Rocky Mountain region.

The evidence from fossils shows, what has not been disputed, that climatic zones were by this time established. In Europe the older Tertiary was decidedly tropical, in the Miocene subtropical, but the climate of Europe was somewhat lowered late in the Miocene, as shown by the absence of palms.[1] At the end of the Tertiary, *i.e.*, during the Pliocene, the earth's climate was but slightly warmer than at present. It should be here noticed that while Greenland, Iceland, Spitzbergen, and Grinnell Land under 81° north latitude were during the late Tertiary "abnormally warm," the Tertiary floras of northeastern

[1] Jaeger suggests that the occurrence in the later geological periods of warm-blooded vertebrates, protected by feathers or hair, was due to the fact that the earth then became cooler than in the preceding ages. His explanation of the origin of feathers and hair is as follows: "If the average temperature of an animal body is considerably higher than that of the surrounding media, oscillations of these media have a stimulating effect upon the skin of the animal. This leads to a tendency to form papillary chorian [*sic*] cells, and these afterwards produce hair or feathers, which represent two of the most characteristic features of warm-blooded animals." He adds that this "stimulatory effect upon the skin can only be due to low temperatures." The body temperature of the birds and mammals being high, and the covering of the hair or feathers rendering them proof against the extremes of heat and cold, we can see that there is a coincidence between this and the fact that these classes began to increase in numbers towards the end of the Mesozoic, and especially at the opening of the Tertiary, when the climatic zones began to be established. So also in the case of whales the loss of hair is compensated for by the blubber. Why, however, feathers developed in birds, rather than hair, is a problem no one has attempted to solve; though feathers of course better adapt the bird for flight; no flightless birds having such well-developed feathers as those capable of extended flight. See G. Jaeger, *Problems of Nature*, translated by Henry G. Schlichter, D. S. C., p. 66. London, 1897.

It might be suggested that the broad, vane-like surface which characterizes feathers as compared with hairs may have been due to the fact that they would better support the body in flight; this difference from scales, as well as their greater lightness, giving this sort of armature an advantage over scales on the one hand and hairs on the other.

Asia, including those of Kamtchatka, Amurland, and Saghalin, and that of Japan, "show no sign of a similar warmth, but rather point to a climate colder than that of the present day" (Kayser, p. 354).[1]

The Tertiary was apparently also a time of more or less intercontinental migrations or interchange of life-forms, which crossed the oceans over so-called continental bridges. Bering Strait was at one time such a bridge, and to explain the geographical distribution of certain forms, there is thought to have been a more or less continuous land connection between India and Africa, and between Africa and South America, and possibly in the Eocene, between Australia and southeastern Asia.

However hypothetical these continental bridges may be, we do know that Central America and the Isthmus of Panama were elevated at the end of the Miocene, and that the bridge thus formed between North and South America became an avenue for the interchange of mammals and other animals which materially modified the distribution of life in the southern and northern parts of our continent.

The elevation of the West Indies took place at this date, and these islands were peopled from the South American coast. What we already know of the rapid evolution of mollusks, insects, and mammals on these islands shows how closely dependent variation and adaptation are on isolation as well as changed topographic and climatic features.

These problems have been studied with great care in the Hawaiian Islands by Gulick, and more recently by Hyatt. As well stated by Woodworth: "With the development of the umbrella-shaped topography of the Island of Oahu the land shells have varied from a common ancestral coastal type to valley-cradled, differentiated varieties, in the upper and disjointed valleys of this dismantled, volcanic island cone."[2]

The limits of this address do not permit us to treat at length

[1] It has also been claimed by J. W. Gregory that the fossil plants of the Greenland Miocene beds may have been drifted from the southward, and that the temperature of the polar region was not so elevated as Heer has led us to suppose. (*Nature*, vol. lvi, 1897, p. 352.)

[2] The Relation between Base-Leveling and Organic Evolution: referring to T. T. Gulick's article in *Proc. Boston Soc. Nat. Hist.*, vol. xxiv (1870), pp. 166, 167.

of the wonderful changes, both geological and zoölogical, which occurred in western America during the Tertiary. They are now familiar to every one. The geological changes were very great and widespread, as shown by the elevation of the land at the close of the Miocene. Fragments of the Cretaceous sea bottom, with horizontal strata, occur in the Rocky Mountains at a point about 10,000 feet above the sea. The inland Cretaceous sea was drained off, and replaced by a series of freshwater lakes, beginning with the Puerco, or the lowest Eocene, and ending with the Pliocene lakes.

The most salient biological features of the Tertiary are the apparently sudden appearance all over the world of placental mammals, ending, if the deposits are truly Pliocene, with the Java Pithecanthropus, and at the beginning of the Quaternary with paleolithic man.

The question here arises as to what retarded the progress in the mammalian types, although small, generalized, feeble insect eaters had originated certainly in the Triassic, and probably as early as the end of the Permian. We can only account for it by the unfavorable biological environment, by the apparently overwhelming numbers of Mesozoic reptiles, adapted as they were for every variety of station and soil, whether on land, in the ocean, in the lakes and rivers, and even in the air.

When the reptiles became partly extinct, a great acceleration in the evolution of mammals at once resulted. There were now upland grassy plains, bordered by extensive forests, which also clothed the highlands, and all the geographical conditions so favorable to mammalian life became pronounced after the Cretaceous seas were drained off.

In his admirable essay on The Relation between Base-Leveling and Organic Evolution, which we had not read until after planning and writing this address, though following the same line of thought, Mr. J. B. Woodworth suggests that mammalian life in the Mesozoic was unfavorably affected by the peneplain and by reptilian life.

"The weak marsupials or low mammals, which first appear in this country with Dromatherium in the tolerably high relief of the Trias, were apparently driven to the uplands by the more puissant and numerous

reptilia of the peneplain. Their development seems also to have been retarded." Again he says: "To sum up the faunal history of the Mesozoic alone, we have seen that *pari passu* with the creation of broad lowlands there was brought on to the stage a remarkable production of reptiles, a characteristic lowland life; and we note that the humble mammalia were excluded from the peneplain or held back in their development, so far as we know them by actual remains, during this condition of affairs until the very highest Cretaceous. At the close of the Mesozoic, the area of the peneplain was uplifted and there came into it the new life. Not only the changed geographic conditions, but the better fitted mammalia also were probably factors in terminating the life of the peneplains."[1]

After the placental mammals once became established, as the result of favorable geographical conditions of migrations, isolation, and secondarily of competition, the evolution as well as the elimination of forms, as is well known, went on most rapidly. Remains of over two thousand species of extinct mammals during Tertiary times which existed in America north of Mexico have been already described, where at present there are scarcely more than three hundred. This process of specialization involved not only the lengthening of the legs, the change from plantigrade to digitigrade, and to limbs adapted for seizing and handling their prey or food, or for swimming and climbing; the reduction of digits; the evolution of armatures, protective scales, etc.; but above all an increase in the mental capacity of the later forms, not only of mammals but of birds, as shown by the progressive increase in size of their brains; those of certain existing mammals being eight times as large, in proportion to the bulk of the body, as those of their early Tertiary ancestors. This, of course, means that animal shrewdness, cunning, and other intellectual qualities, the result of semi-social attrition and competition, had begun to displace the partly physical factors, and in the primates these may have in the beginning led to the appearance of man, a social animal, with the power of speech, and all the intelligent, moral, and spiritual qualities, which, perhaps, primarily owe their genesis to increased brain power.

The three most specialized types of mammals below men are the horse, the bats, and the whales. In the case of the

[1] *American Geologist*, vol. xiv (October, 1894), pp. 209–235.

bats, which appear in the Eocene, nature's experiment with these mammalian aëronauts succeeded to the extent that they still exist in small numbers. Late in the Cretaceous or very early in the Eocene, competition apparently forced some unknown carnivorous type to take up an aquatic life, and the great success of the incoming cetacean type, resulting in the Eocene zeuglodonts and Miocene squalodon, may have had an influence on the final extinction of the colossal marine reptiles.

6. *The Quaternary Period.* — Coming now to the glacial epoch of the Quaternary period, we plainly see that under the extreme conditions to which life in the Northern hemisphere was exposed as never before, how intimate are the relations of geology and biology.

The rise of land at the beginning of the Quaternary, which carried the land and the life on it up into a cooler zone, with a mean temperature so low that the snows remained from century to century unmelted, forming continental glaciers, excited an immediate influence on the life. There were very soon developed a circumpolar flora and fauna, originating from the few Pliocene forms, which became adapted to climatic conditions more extreme than ever before known in the world's history. While a few forms thus survived, some must have perished, though the bulk of them migrated southward.

The story told by the Port Kennedy hole, in Pennsylvania, just south of the limits of the ice sheet, is a most striking one. In that assemblage where are intermingled the bones of mammals of the Appalachian subprovince, with certain extinct forms, and those of the tapir and peccary and colossal sloths, adapted to the warmth of the Pliocene, and of the present Central American region, we can realize as never before the immediate effect of a simple though very decided change of climate on organic life.

As a result of the submergence of the land in the North Atlantic and Arctic regions during the Leda or Champlain epoch succeeding, and the consequent amelioration of the climate, there was a return of a portion of the Pliocene species to the vast area thus freed from the presence of land ice.

Another effect of change of climate due to the further upheaval, drainage, and drying up of lakes and river sources in the central portions of all the continents was the destruction of forests resulting from the drying up of the lakes and streams, the formation of vast internal desert regions, with the desert floras and faunæ and saline animals peculiar to them; these are the last steps in geological history of the origination of species, and have been taken almost under the observation of man. In the origin of species adapted to desert areas and to salt lakes, *faunæ relictæ* of the lakes on the elevated plains of Asia, South America, Africa, Sweden, and the Great Lake region, we see that geographical isolation and the absence of competition are the primary factors in the case.

In conclusion, it is, from the nature of the case, notwithstanding the imperfection of the geological record, apparent that the fullest, most complete and convincing proof of organic evolution is derived from the past history of life, from paleontology, which involves the fact of geological succession. Looking back for half a century, we see that organic evolution is a fact, and is grounded and dependent on geological evolution, and the latter on cosmical evolution. Should we ever have to abandon the principle of evolution, we should also have to give up the theory of gravitation, the principle of the correlation of physical forces, and also the conception of the unity of nature. All of these principles are interdependent, and form the foundation stones of our modern science.

The rapid summary we have given of the successive changes and revolutions in the earth's history, and the fact that they are accompanied or followed by the process of the extinction of the unadapted, and their replacement by the more specialized and better adapted, show that there is between these two sets of phenomena a relation of cause and effect.

Moreover, it cannot be denied that the formation of our solar system in the manner outlined by the founders of the nebular hypothesis, that the progressive changes in geology and the earth's topography, the gradual building up or evolution of the continents, and the increasing fitness and intelligence of the life on its surface, the final outcome being man, whose physical

development was practically completed at the beginning of the Quaternary period, and whose intellectual and moral improvement have, as it were, but just begun — the scientist, as such, can scarcely deny that this process of evolution, along so many lines and involving not only material but mental and moral advances, has gone on in an orderly and progressive way. The impression left on the mind is that all these changes, inorganic and organic, have been purposive rather than fortuitous, the result of the action of natural laws, impressed on matter by an intelligence and force outside of, but yet immanent in, all things material.

With Hutton we may say: "We have now got to the end of our reasoning; we have no data further to conclude immediately from that which actually is. But we have got enough, — we have the satisfaction to find that, in Nature, there is wisdom, system, and consistency."

Here, as men of science merely, we may pause and confess our ignorance of the first or ultimate cause of this progressive evolutionary movement pervading the material universe, and, suspending our judgment, assume an agnostic position. But the human mind, even when rigidly scientific and logical, is so constituted that few of us are satisfied to stop here. He who is most capable of daring speculation in the realm of physical or biological or philosophical thought cannot refrain from inquiring into the nature of the first or moving cause, and how the present order of things has been brought about.

As a mere working hypothesis, we are, at least most of us, compelled to assume that the present order of things, material and immaterial, is not self-evolved, but is the result of an infinite Intelligence and Will, giving the initial impulse, and dominating as well as guiding and coördinating the progressive changes, whether cosmical, geological, or biological. The fact of the survival of the fittest, of the extinction of the unfit, the conclusion that throughout the universe order has arisen from chaos or the undifferentiated, the specialized from the generalized, that the good and beautiful and true have in the past overcome and will continue to outweigh what is unfit and evil in matter, mind, and morals, at least strongly suggests that the

First Cause is not only omnipotent, but all-wise and beneficent. For evolution tends to optimism. Few working biologists are pessimistic. And thus, while science as such is concerned with facts and their relations, we can, at the end of this century of scientific effort, affirm that it need not be and is not opposed to whatever is noble, exalted, hopeful, and inspiring in human aspirations, or to the yearnings of the soul for a life beyond the present; for there certainly are, in the facts of the moral and spiritual evolution of our race, intimations of immortality, and suggestions, where absolute proof is naturally wanting, of a divinity that shapes the course of nature.

THE CONCEPTION OF SPECIES AS AFFECTED BY RECENT INVESTIGATIONS ON FUNGI.[1]

W. G. FARLOW.

THE fiftieth anniversary of the foundation of the American Association is a fitting occasion for a retrospective view of the different branches of science represented in our Society, and one would be glad to hear, from the lips of some botanist who was present at the first meeting of the Association, an account of the changes which have been brought about in the methods of botanical study and research, and of the progress which has been made in North America during the past half-century. Fifty years, however, is a long time in the life of any individual, and of those who in 1848 were young, or comparatively young, even the most favored could hardly be expected to retain their scientific activity in 1898. On glancing over the list of members in 1848, one sees the familiar names of a number of botanists, including Ashmead, J. W. Bailey, Barratt, Jacob Bigelow, Buckley, Dewey, Emerson, Engelmann, L. R. Gibbes, Gray, B. D. Greene, Edward Hitchcock, Oakes, Olney, Pickering, Thurber, Torrey, and Tuckerman. Not one of these leaders of American botany in their day remains to tell us of the Association in its infancy and to trace its development with the vividness which personal experience alone can supply.

It would be scarcely fitting in me to attempt to give a general sketch of the part which botany and botanists have played in the life of the Association; nor, remembering the review of recent investigations in botany presented by Prof. Marshall Ward at the meeting in Toronto last year, is it desirable that I should encroach on the ground so thoroughly and so interestingly covered by him. I may, however, on this occasion, be permitted to say a few words on a single question on which opinions have changed very much during the last fifty years,

[1] Address of the Vice-President and Chairman of Section G, Botany, at the fiftieth anniversary meeting of the American Association for the Advancement of Science, Boston, August, 1898.

and, avoiding a detailed history of the subject, treat it somewhat abstractly in its general bearings; for the question, you will admit, is one about which we should occasionally ask ourselves what is probably or possibly true, without, however, expecting, in most respects, to be able to reach positive conclusions. What do we mean by species? Do species really exist in nature, or are they created by us for our own convenience? As I do not pretend to be in the position of a philosopher, but approach the subject as a very commonplace sort of a botanist, the word species, as used by me, means simply species as understood by the systematic botanist, and indirectly by those working in other departments of botany who are obliged to depend to a considerable extent upon the limitations of species as defined by systematists.

The publication of the *Origin of Species* in 1859, a date which marks the fall of the old school and the rise of the new, is sufficient to show that it is not probable that any other period of fifty years in the future will have the same comparative historical importance, as far as the question of the conception of species is concerned, as the fifty years we are now commemorating. Had we asked any of the botanical members of the Association in 1848 what they meant by species, they would have replied, most of them without reserve, a few with some hesitation, that in the beginning God created all species as he intended them to be, and that, by searching, the naturalist could find them out. Just how they recognized species when they saw them would have been very hard for them to say, as they did not agree in their standards; but they would probably all have agreed in saying that the recognition of species was a matter of individual judgment, one's own judgment, of course, being better than that of any one else. The sceptic at that time could not have failed to notice the frequency with which what was home-made was confused with what was God-given. Before 1859 creation was one vast pudding, in which the species had been placed like plums by an Almighty hand, and the naturalists, sitting in a corner like greedy little Jack Horners, put in their thumbs and pulled out the plums and cried, "See what a great naturalist am I — I have found a new species!"

Probably very few of my hearers have any personal recollection of the time when not to believe that species were fixed and immutable creations was enough to make one a scientific and almost a social outcast. I recall but a few people whom I knew who held these orthodox views, for it was my good fortune to be a student in college at the time of the appearance of what was called "a new edition of the *Origin of Species*, revised and augmented by the author," published by D. Appleton & Co. in 1864. By that time the novelty and audacity of Darwin's views had ceased to cause a cold shudder, and certainly the students of my time were ready to swallow not only what Darwin had written, but to add a few little theories of their own.

The young botanist of to-day will, I think, pardon me, although my contemporaries may not, if I give a short sketch of the Harvard Natural History Society in the sixties, as showing not only how changed is the position of Natural History in American colleges, but also the attitude of college students at that day toward the then new doctrine of evolution. If the Society soon after my college days passed out of existence, its end could not be said to be untimely, for the attitude not only of the university but of the scientific public towards the study of natural history had so changed that the old-fashioned Society had no place. Those of you who go to Cambridge next Friday may perhaps see a dreary, barn-like sort of a lecture-room which now occupies the greater part of old Massachusetts Hall. In days gone by the three upper stories of the hall served as dormitories, and the lower story was occupied by the rooms of the Natural History Society, sandwiched in between those of the Institute of 1770, which then was pleased to consider itself to be a literary society, and the laboratory of the Rumford Chemical Society, which, as it emitted none of the odors characteristic of chemical activity, must be considered in my day to have been moribund, if not actually defunct.

The rooms of the Natural History Society would now cause a smile. From the low ceiling were suspended an alligator, a turkey buzzard, and such other creatures as would not fit well in the wall cases. In one corner leaned lazily a large cup sponge, a receptacle for the dust which gravity constantly supplied and

the rejecta contributed at frequent intervals by the members. Around the walls was a very promiscuous collection of birds and mammals, some shot and prepared by past members, others the gift of so-called benefactors, who, not knowing what else to do with them, turned them over to the Society. Quartz crystals and other showy but not very valuable minerals hobnobbed with skeletons, one of which, at least, must have been very useful, if one could judge by the perennial absence of some of the limbs, which had been removed, as was said, for study.

Botany was represented by a single cabinet, whose pigeonholes were filled with plants of New England, enriched by choice fragments of specimens collected by well-meaning persons in the Alps and by travelers in the Holy Land. The plants were arranged, or rather shuffled, in the case according to the wishes or necessity of the curator of the time being. We were quite eclectic in our view of botanical classification, some pigeonholes being arranged on the Linnæan system, some on the natural system, and some apparently alphabetically. Whatever real value the collections may have had, once a year they were at least ornamental. Every year the members were photographed, and the alligator, the turkey buzzard, and the human skeleton were taken down and added to the group to show that we were really the Natural History Society, and not the Hasty Pudding or the Phi Beta Kappa.

The old collections were long ago dispersed, and the little which was of value is now incorporated with the different university collections. You may perhaps be curious to know what the members of the Society did. That is easily told. They all talked, and some dissected cats. The talk was to a great extent about the origin of species, and, no matter what was the subject of the papers announced for the evening meeting, it was not often that we adjourned without dropping into a discussion of evolution. Few had really read Darwin's book, but all felt able to discuss the great scientific question of the day, in which respects, perhaps, we did not differ from some older and more learned people. Although the traditional man who is always on principle "on the other side" was not wanting, we were practically unanimous in our opinion. We all

felt that a new day had dawned; that the old view of looking at species as fixed creations, and ignoring as far as possible the significance of their tendency to vary, had been forever upset by Darwin, and that hereafter we must look to evolution as brought about by natural selection to interpret species as we now find them. Not being well informed in regard to the history of scientific opinion, we assumed somewhat hastily that before Darwin all was darkness, and we did not trouble ourselves to go back and inquire whether there were not others who had had at least glimpses of the great truths of evolution; but even had we heard that there were some before Darwin who did not believe in the fixity of species, it would still have been true that it was Darwin's book by which, practically, the world at large was enlightened on the subject.

Forty years have passed, and inasmuch as we are all evolutionists, either of the Darwin school or some related school, the question suggests itself, Is our belief in evolution merely dogmatic, like some of the theological doctrines which we believe thoroughly but which we do not allow to interfere with our daily life, or, as far as botany is concerned, has our belief modified the manner in which we treat what we call species? The mere fact that we now recognize that species have been derived from other species, and are on the way to develop into still other species, would naturally lead us to be more liberal in our treatment of them systematically than in the days when variation was almost a crime against the Almighty. Certainly, with evolution as a key to guide us, our conceptions of genera and orders ought to be far more scientific than they were.

A species has been defined as a perennial succession of like individuals; and, although no definition is perfect, I doubt whether a better definition of species has ever been invented. It is a peculiarity of definitions, however, that they all need to be defined. In the present case we must be told what is meant by the word perennial, and what is meant by like. To the pre-Darwinian, perennial, of course, meant for all time. By the early Darwinians we are not told whether by perennial they meant a hundred, a thousand, or a million years; but until at least we know approximately what is meant, we must still ask

how long must be the succession of like individuals to establish a good species. Otherwise the whole matter of the distinction between a race and a species cannot be settled practically. If there is nothing definite in writings of the time of Darwin to explain the limits of the perennial succession, we should bear in mind that the object then was to bring out boldly the salient points of evolution as governed by natural selection, and the illustrations used were taken almost exclusively from the higher animals and plants in which the lives of individuals are of such duration that it was impossible to obtain accurately the records of a large number of generations in any case. Enough was shown and cited to show from the records of comparatively few generations a general tendency, which it was assumed would be confirmed could the geological record be followed, and we can suppose that, so far as they considered the question at all, the early Darwinians took it for granted that the perennial succession needed to establish a species covered very long intervals of time. While one need not object to this method of reasoning, it is plain that the practical question of when a race or variety ceases to be a race and becomes a species was left open, and it is questions of this sort which the systematist is constantly called upon to answer.

What could be learned only slowly and fragmentarily from observations and experiments on higher plants and animals might perhaps be learned much more easily could one experiment with organisms whose cycle of life is completed with great rapidity. For this purpose one might suppose that nothing could be better than bacteria, which are easily managed in the laboratory, and whose development takes place with such rapidity that it is possible for the experimenter to watch the course of hundreds or even of a thousand generations in a comparatively short time.

The advantage to be expected from studying forms in which the development is very rapid is, however, made difficult for purposes of comparison by their extreme simplicity and the difficulty, and at times impossibility, of finding sufficiently marked morphological characters to guide us; and in the absence of such characters the bacteriologist is often forced to base what

he calls his species on physiological characters, including in that term zymotic and pathological action. By botanists, who are not specially bacteriologists, the so-called species of bacteria are not admitted to be species in the proper sense. Whether scientifically considered they are not as legitimately species as what are called species in speaking of the higher plants, is a very pertinent question. Any definition of species, to be scientifically accurate, must in its essential points apply to all plants and all animals; and if a species of flowering plant is a perennial succession of like individuals, it is hard to see why in bacteria a perennial succession of like individuals does not also constitute a species. That the individuals in bacteria are very different from the individuals in flowering plants is certainly true, but that does not affect the question of the validity of the species in the former. As far as the perpetuation of morphological likeness of the individuals is concerned, there is no doubt that it is, to say the least, as complete in bacteria as in flowering plants, and the physiological constancy has been shown by competent observers to persist in some cases for hundreds of generations. That these many generations have been produced in months rather than in hundreds of years does not, it seems to me, affect the case.

When, therefore, the botanist denies that physiological species are properly species, he is practically admitting that his own definition, the perennial succession of like individuals, is used by him in a special sense, and he does not seem to be aware that species as he limits them are artificial and not natural. The belief that species should be based on morphological rather than physiological characters rests on the assumption that the former are more likely to be inherited, and thus show the ancestry, while the latter are more likely to be the result of the temporary attempts of the organism to adapt itself to the environment. It is perhaps a question whether the grounds for this belief are as valid as has been supposed. We readily see morphological characters which have been inherited, but it is usually only by accident or experiment that we recognize the physiological or pathological qualities.

Let us turn for a moment from bacteria to Saccharomycetes,

whose characteristic function is to invert and ferment the different sugars. Here we have a group much more limited in number of species than the bacteria, but like them microscopic and rapidly growing. Although not long ago they were classified after a fashion on their morphological characters, the admirable investigations of E. C. Hansen and his followers have pointed out the important fact that these characters, taken by themselves, are less fixed, although the limits of their variation may be fixed, than certain physiological characters such as the maximum and minimum temperatures of growth, and especially the temperature at which spore formation takes place. It is in these last-named characters, rather than in the former, that the specific distinctions in Saccharomycetes are sought by those who study that group specially.

The same objection is urged by botanists in this as in the case of bacteria, that the so-called species are not species, but races. We naturally ask, races of what species? There have been many attempts to determine the origin of the common Saccharomycetes, and the question has been supposed more than once to be settled. Without intending to imply that the question is not still open to investigation, I must admit that there does not yet seem to me to be any satisfactory proof to show from what higher forms Saccharomycetes have been derived. Although there can be no doubt that in the germination of spores of certain fungi, especially the Ustilaginaceæ, bodies are produced in abundance which not only closely resemble Saccharomycetes in shape, but also, in some cases at least, are capable of producing alcoholic fermentation to a limited extent, it does not seem to me that that is by any means enough to warrant the opinion expressed by Brefeld that the Saccharomycetes are derived from, and are degenerate conditions of, Ustilaginaceæ. In fact, one has only to consult Brefeld's own writings to see that Saccharomycetes-like bodies are produced by the germinating spores of other orders of fungi than Ustilaginaceæ, and it is known that, in some species, as in the genus Aspergillus and in certain Mucoraceæ, the budding cells which look like the Saccharomycetes, using the word in the limited sense, are also capable of producing alcoholic fermentation.

On the other hand, no one has yet succeeded beyond a doubt in making the Saccharomycetes proper revert to a higher ancestral form. I say beyond a doubt, because the observations of Juhler, Joergensen, and Johan-Olsen, on the relation of Aspergillus, Sterigmatocystis, and Dematium, to Saccharomycetes, have not been confirmed by other equally good observers, as Kloecker and Schioenning; and, for the present at least, we must regard the observations of Joergensen and Johan-Olsen as affording still other instances of the fact that under proper conditions the germinating spores of many fungi produce bodies like Saccharomycetes, while they do not show conclusively that forms recognized by specialists as genuine Saccharomycetes can be transformed into fungi of other orders. They do, however, show that the views of Brefeld that the Saccharomycetes are derived from Ustilaginaceæ could, at the best, be only partially true.

Let us return to the question as to whether or not species of the Saccharomycetes, as defined by Hansen for instance, should be allowed to be called species in the proper sense of the word. Of course no one supposes that they have always existed in their present form, and, although we have no exact knowledge of the ancestors of the present species, we naturally suppose that they were derived from some other higher fungi, as the expression goes. Whether derived from one particular order of fungi or from several different orders, the species as we now see them seem to be constant in the sense that that word must be used in speaking of species of any group of plants. The shape of the cells in any given species, although variable to some extent, is constant within definable limits, and, although they have periods of rest and periods of activity, their physiological action seems to be the same under similar conditions.

We might be justified, it seems to me, in regarding as races the Saccharomycetes-like forms which result from the germination of spores of higher fungi, provided they continued to live an independent existence for a time and were not, as is more likely to be the case, merely accidental conditions depending on unusual or unfavorable conditions of germination, but the Saccharomycetes in the limited sense are constant, as far as

constancy is to be expected in living organisms in general; they cannot be made to revert. as far as we know, and I therefore fail to see why they should not be admitted to be scientific species. The same is true of the physiological species of bacteria, meaning, of course, those which have been well studied, and excluding the mass of ill-described and ill-known forms which abound in bacteriological writings. When a race has become so constant that it no longer reverts, and we cannot tell from what species it came, it is no longer a race, but a species.

It may be objected, however, that both bacteria and Saccharomycetes differ from ordinary plants in a most important respect, *viz.*, that there is a complete absence of sexuality and the reproduction is purely vegetative. There are a few botanists, to be sure, who think that there is a form of sexuality in Saccharomycetes, but botanical opinion at present is so overwhelmingly on the other side that to call the question an open one would require an explanation which time will not permit. It may be urged that in plants in which sexuality is wanting we have no right to speak of a perennial succession of like individuals, for, it may be claimed, succession means by sexual generation only. This interpretation is very convenient if one wishes to ignore forms like bacteria and Saccharomycetes in the consideration of the question of species, but to exclude them on this ground is somewhat dangerous unless we are prepared to admit, offhand, that species are purely artificial.

It is the custom to speak of bacteria and Saccharomycetes as degenerate forms. What is meant by this expression is not plain, unless it means that, arising presumably from plants in which sexuality was present, they have become non-sexual. Undoubtedly sexuality is the rule in nature, but it should be borne in mind that it is not universal. I do not refer here to fungi like Ascomycetes and Basidiomycetes, which, accepting the hasty conclusions of the Brefeld school, have been, even by a good many of our own botanists, included in the limbo of non-sexual degenerate forms, from which more recent observers are gradually rescuing them. I refer rather to species like *Rhodymenia palmata*, one of the commonest red seaweeds of the North Atlantic, in which, so far, nothing has been discov-

ered but the non-sexual tetrasporic reproduction. This is not an isolated case, and others will probably occur to my hearers. Furthermore, we must admit that the number of species normally sexual, but in which apogamy sometimes occurs, has been perceptibly increased by the studies of botanists in recent years. In such cases as that of Rhodymenia it may be that the cystocarpic fruit really exists, and will be found later, but, since botanists have searched for it in vain for many years, it must be very rare, and certainly, as far as we know it, the plant is non-sexual.

In regard to cases of apogamy, we have not yet sufficient data as to their capacity for propagating themselves continually apogamously, although in such cases as that of *Chara crinita*, if we may judge by the distribution of the species in central Europe, there seems to be no reason to believe that they may not do so indefinitely. The not inconsiderable number of species of mosses, some of them common species, in which the male or female only is known, and the number of marine algæ, which, in spite of their frequency, bear only tetraspores, or at most bear cystocarps very rarely, should make us cautious in so defining what we mean by species as to imply that we consider that the perennial succession refers only to succession by sexual generation.

We cannot fail to notice an increasing tendency among cryptogamic botanists to give more and more weight to physiological characters in limiting their species. For some time we have been accustomed to think of the species of bacteria as largely physiological, and we are gradually accustoming ourselves to the views of those who hold the same view in regard to species of Saccharomycetes. More recently still we find that in another higher order of fungi, the Uredinaceæ, experts are coming more and more to rely on physiological characters. If in bacteria and Saccharomycetes we have plants which are generally recognized to be non-sexual, in Uredinaceæ the probability is that there is sexuality; at least, the probability is here much stronger than in the other two groups. By some the sexuality of Uredinaceæ is considered already proved, but admitting that the form of nuclear union demonstrated by Dangeard and Sappin-Trouffy, and confirmed by some other botanists, must have some impor-

tant significance, not only in this but in other orders of fungi where it occurs, there are reasons for not regarding the union in this case as representing true sexuality. On the other hand, although no one has as yet quite proved it, there appear to be reasons for supposing that, in the æcidial stage, a form of true sexuality occurs, comparable with what is known in some ascomycetous fungi. Time alone will show whether this present probability is a reality, but at any rate the position of Uredinaceæ in regard to sexuality is undoubtedly very different from that of bacteria and Saccharomycetes.

One who takes up the recent descriptive works on Uredinaceæ is surprised to see the number of species which depend on physiological characters. The former method of describing the species of this order from the morphological characters of the teleutosporic, the uredosporic, and æcidial stages, was certainly sufficiently perplexing, but one almost gives up in despair on seeing species in which the different stages are identical in all respects, except that some of them, usually the æcidia, will grow only on certain hosts. Facts like this are of course only determined by artificial inoculations, although they may sometimes be suspected by the distribution of the different stages in nature. In this complicated state of things, more complicated than in any other order of plants, we are compelled to examine very critically the accounts of cultures made even by botanists of high reputation, and it is only natural that we should hesitate to give implicit confidence to negative results unless the observations have been repeated by other observers at other times and places. Even from scattered positive results one should avoid drawing too wide general conclusions. We may readily believe that some of the supposed distinctions in the choice of their hosts by different Uredinaceæ will be proved hereafter not to be founded in fact, but, making all proper allowances for possible errors in observations and for hasty speculation in a field where speculation is so easy, and accurate experiment so difficult, we have to admit that in a good many cases surprising results have been confirmed by repeated observations, and the tendency to split up species on physiological grounds becomes more and more marked.

As the subject is somewhat complicated, it will be well to consider a few prominent cases by way of illustration. An instructive case is that of the Puccinia on *Phalaris arundinacea*, referred to, among other subjects, by Magnus and Klebahn in papers published in 1894 and 1895. To the teleutospores was originally given the name *Puccinia sessilis* Schneider, which was found by Winter to bear its æcidia on *Allium ursinum*. Later Plowright experimented with a species which grew on Phalaris whose teleutospores could not be distinguished from those of *P. sessilis*, but whose æcidia could be produced on *Arum maculatum*, though not on Allium. To this physiological species Plowright gave the name of *P. phalaridis*. Still later Soppit discovered that a Puccinia indistinguishable from *P. sessilis* and *P. phalaridis* in its teleutospores produced its æcidia on *Convallaria majalis*. To this species he gave the name of *P. digraphidis*. Had these observations not been confirmed by others we might have doubted whether Winter, Plowright, and Soppit had not really experimented with the same species of Puccinia, but, owing to some accident of their cultures, had succeeded in inoculating only different hosts, whereas it might well be the case that the æcidia on the three hosts might by subsequent cultures prove to be the same; and, in that case, *P. sessilis* would really be only an instance of a Puccinia which produces æcidia on three different hosts, not an infrequent case. The observations of Magnus showed that *P. digraphidis* bore æcidia also on Polygonatum and Maianthemum, genera closely related to Convallaria. So far as concerned Polygonatum and Maianthemum, Soppit and Magnus's observations were confirmed by Klebahn. The case is complicated by a difference of opinion as to whether the æcidium on Paris is connected with *P. digraphidis*, or whether there is not a fourth distinct species, *P. paridis*, as believed by Plowright.

We need not stop to consider the further history of this complicated case, as it is introduced here merely to illustrate the method and tendency of recent workers in this field.[1] The above-named botanists, who studied the species of Puccinia on

[1] Those interested in the subject should consult Klebahn, "Ueber den gegenwärtigen Stand der Biologie der Rostpilze," in *Botanische Zeitung*, May 16, 1898.

Phalaris, seem to agree in speaking of *P. sessilis*, *P. digraphidis*, and *P. phalaridis* as distinct species, although Plowright considered *P. paridis* to be distinct from *P. digraphidis*, whereas Magnus considered the two to be what he calls adaptive races (Gewohnheitsracen) of the same species. Magnus speaks of the three species as biological species, which he distinguishes from adaptive races, the latter including forms in which, although the æcidium may be produced on different hosts, it does not appear to be so frequent or so well developed on some hosts as on others, showing in the one case that the adaptation is more complete than in the other. Klebahn, although admitting that it is not of real importance whether one regards such forms as the Pucciniæ on Phalaris as species or races, nevertheless states that he sees no reason why they should not be considered to be genuine species rather than races.

Another instance in point is the group of æcidia generally known as species of Peridermium, which infest species of Pinus. It had for some years been recognized that the æcidial stage of the corticolous form of *Peridermium pini* was not the same as that of the form on the leaves, but in recent years the subdivision has been carried much farther, owing to cultures made by Klebahn, Edouard Fischer, Rostrup, and others. The former has distinguished at least seven species of Peridermium on *Pinus sylvestris* alone, whose uredo and teleutospores are to be found in the species of Coleosporium, which grow upon different genera of Compositæ, Scrophulariaceæ, and Campanulaceæ. Although Klebahn is inclined to see minor differences in the shape and markings of the æcidial spores of some of the species, it must be admitted that the differences in some cases are so slight, both in the case of the æcidial spores and the corresponding teleutospores, that, were it not that cultures show the connection between the form on one host with that on another to the exclusion of other hosts, it is hardly likely that many botanists would consider them as distinct species.

The most suggestive Uredinaceæ for our present purpose are the different species of Puccinia which attack grains and other grasses, for a knowledge of which we are indebted to the

researches of Eriksson and Henning in Sweden, whose work is certainly a model of careful investigation. I take it for granted that most of my hearers are already acquainted with the character of the work in question, and we need stop to consider only those points which bear upon the subjects we are discussing. Of the three common rusts which affect grains, *Puccinia graminis*, *P. rubigo-vera*, and *P. coronata*, the æcidia are to be found, respectively, in *Æcidium berberidis*, *Æc. asperifolii*, and *Æc. rhamni*, according to the previously accepted view in regard to those species. Judging by the morphological characters of the teleutospores and the uredospores alone, these three species occur on a large number of different grasses. In making inoculations to ascertain the facts in regard to the æcidia of the species, Eriksson and Henning found that what was supposed to be *P. graminis* growing on *Phleum pratense* and *Festuca elatior* had no æcidia, and they described this form under the name of *P. phlei-pratensis*. *Puccinia coronata* is separated into two species, *P. coronifera* and *P. coronata*, the former having its æcidium on *Rhamnus catharticus*, the latter with æcidia on *Rhamnus frangula*, with perhaps two other forms to be separated from the old *P. coronata*. *Puccinia rubigo-vera* is separated into three species : *P. glumarum*, *P. dispersa*, and *P. simplex* — the distinctions based largely on the presence or absence of the æcidium, although there are also certain differences in the habit and color of the other stages. The three original species are split up into seven species, besides two uncertain forms, characterized in the main by physiological characters. Furthermore, of *P. graminis*, six specialized forms are enumerated, characterized by differences in the inoculating capacity of the uredo or teleutospores on different hosts. The other species also have their specialized forms, the total number being, I believe, twenty-eight. We may consider the specialized forms to be races, and, in that case certainly, we shall have to agree with Eriksson and Henning in considering their seven species as species rather than races. The important point is to know whether the differences observed are temporary and accidental or permanent. It is too much to ask for the confirmation of the results of these two experimenters just

now, for their work is recent and has been carried so far beyond that of previous experimenters that it must require a considerable number of years before we can expect the work to be repeated by others. So far as the experiments have been repeated, as in the case of *P. coronifera* and *P. coronata,* it has been confirmed.

Enough has been said to show that the conception of species by those who are doing the most advanced work in fungi is much more flexible than it used to be, and significance is to be attached to the fact that the number of those who, as viewed by the typical systematic botanist, hold very heterodox views is increasing. The explanation is to be sought in the fact that descriptive botany in certain groups of plants has reached a point where the ordinary morphological characters no longer suffice to classify what we know or wish to know about the plants themselves. It was my privilege eleven years ago to address what was then the biological section of the Association on a subject somewhat related to that of to-day, and my closing sentence then was: "Following the prevailing tendency in business affairs, the question they [botanists] ask of plants is not so much, 'Who is your father and where did you come from?' as, 'What can you do?'"

The tendency noticed eleven years ago is even more marked at the present day. As compared with the times of which I attempted to give a sketch in my opening remarks, I think we may truly say that whatever may be the case in zoology, in botany theoretical considerations with regard to evolution play a much less important part than they used to. In the case of such plants as Lycopodiaceæ, Equisetaceæ, and their allies, and of certain orders of phanerogams, the ancestral question naturally remains as important as ever; but, although papers on other orders of plants, accompanied by hypothetical genealogies and family trees of the banyan type, appear at not infrequent intervals in botanical journals, they are quite overshadowed in general interest by the papers on cytology, life histories, and physiology. That was not the case in the sixties, when nothing compared in interest with the question of the origin of species. While we cannot be too grateful to Darwin for having opened

our eyes to see the value of evolution in general, the majority of the active botanists of the present day find too many other pressing questions to be solved to be able to dwell on evolution to the same exclusive extent as did the botanists of the last generation.

Our definition of a species included two terms which required further explanation. We started out in the hope of finding some light as to the approximate length, or at least the approximate minimum of the length of time which is needed to transform a race into a species, hoping that perhaps those plants in which the development of the individual was rapid might show that in a comparatively short space of time a race might be actually observed to become fixed and be considered a species; a fact which certainly could not be so well ascertained by direct observation in the study of the higher plants alone. You will notice that, like the obliging shopkeeper, I have not given you exactly what you expected, but have offered you instead something else perhaps just as good, if not better. If I have not been able to tell you that in such simple and quickly growing plants as bacteria and Saccharomycetes new species can be produced from old ones in a comparatively short time, a consideration of some of the peculiarities of such plants has brought out the modifications which have taken place in the views of a good many as to specific limitations, which is in part an answer to our primary question, What do we mean by a species?

It may be added that although some of the species of lower plants may be transformed in various ways by artificial cultures, on the whole we are quite as much struck by their comparative constancy in important respects as by their tendency to differentiate. In Uredinaceæ there is a tendency to form adaptive races, which is greater than was formerly supposed; but whether the tendency is greater than would be found in some higher plants, were they studied as carefully as have been the Uredinaceæ, is perhaps a question. Parasites, as a rule, are more plastic and more sensitive to changes of environment than other plants, and their impressionability, if I may use that word, might be expected to accentuate their power of specific transformation. It cannot be denied that there is a general suspicion, to say knowl-

edge would be too strong, that the lower plants become specifically changed more easily and quickly than the higher; but although this is what we should expect from their more rapid individual growth, I am not able to cite any actual observations which can settle the question; for, as you know, the school of botanists, which may be called the school of ready transformationists, have a fatal tendency to accept unskillfully conducted or otherwise faulty observations as convincing proofs. Others, it is to be feared, err on the other side, and are not sufficiently ready to admit metamorphoses in different species of the lower plants. Probably the truth lies between the two. The metamorphoses to which I now refer are, of course, in the normal cycle of individual development and should not be confused with the differentiation into races and species, but of necessity our views as to the latter must be influenced to some extent by our attitude towards the former.

If we turn to the second word of our definition which needed explanation, and attempt to say what is meant by like individuals, we find ourselves wholly at sea. Even if we agree that the likeness must be morphological and not physiological, that does not help the matter at all. No two individuals are ever absolutely alike in morphological characters, and the question is one of comparative likeness only. Systematists may agree that certain characters are more important than other characters, but they would never agree as to what characters are important enough to be regarded as specific in comparison with those which are only racial. In fact, when we come to the point, we find that most systematists do not in practice distinguish species from races on the ground that the former are practically constant, whereas the latter are not, but rather on the ground that they regard the characters which they use to distinguish species as more important than those which they are willing to accept as merely racial.

But what is more important and less important is a question not only of individual opinion at any given time, but it is also a question which depends on the means of analysis at our disposal, and these change from time to time. Surely there never lived a better systematist than Elias Fries, and at the time of

its publication, in 1821–32, his *Systema Mycologicum* was certainly a masterpiece. If the species described by him in genera, such as Sphæria, for example, which were then considered valid, are no longer recognized as such, it is not because in limiting his species as he did Fries did not employ with remarkable skill the same scientific principles of classification as the mycologists of to-day, but mainly because the modern application of the microscope to the study of the spores and some other characters has brought out facts unknown at the beginning of the century. The species of Fries have been split up and changed in many respects, and while we feel sure that the modern classification, thanks to improved microscopes, is an improvement on his, who shall dare say that hereafter some present unknown and unsuspected method of analysis may not furnish facts which will overturn our present system?

I should feel that I ought to apologize for bringing up a subject so very, very threadbare, were it not that some botanists shrink from acknowledging the fact that what we botanists call species are really arbitrary and artificial creations to aid us in classifying certain facts which have been accumulated in the course of time, and nothing more. So long as we entertain even a lingering suspicion that they are anything more, systematic botany will not be able to accomplish its real object, which is certainly very important. We are all convinced, theoretically at least, that not only are all plants gradually changing, and sooner or later will no more be what they now appear to us to be than they are now what they were in times past, and we also know that the means which we have of studying them are changing as well. Our so-called species are merely snapshots at the procession of nature as it passes along before us. The picture may be clear or obscure, natural or distorted, according to our skill and care, but in any case it represents but a temporary phase, and in a short time will no longer be a faithful picture of what really lies before us; for we must not forget that the procession is moving constantly onward, and at a more rapid rate than some suspect. Better cameras will be invented, and when another generation of bota-

nists snap off their pictures, they will undoubtedly look back with pity, if not with contempt, on our faded and indistinct productions.

Whether or not species really exist in nature is a question which may be left to philosophy. Our so-called species are only attempts to arrange groups of individual plants according to the best light we have at the moment, knowing that when more is known about them our species will be remodeled. We should not allow ourselves to be deluded by the hope of finding absolute standards, but it should be our object to arrange what is really known, so that it can be easily grasped and utilized. Utility may, perhaps, sound strange, and may seem to some to be a very low aim in science, but in the end utility will carry the day in this case, for systematic botany is a means, not an end. Its true object should be to map out the vegetable kingdom in such a way that all known plants are grouped as clearly and distinctly as possible, in order that the horticulturist, the forester, the physiologist, may be able to obtain the facts needed by them in their work. Our present knowledge may not be sufficient to enable us to draw all the contours sharply, or to lay down accurately all the lines, but our work certainly should not be blurred by subtleties and purely metaphysical refinements. The best systematist is not he who attempts to make his species conform to what he believes to be the ideal of nature, but he who, availing himself of all the information which the histology, embryology, and ecology of the day can furnish, defines his species within broad rather than narrow limits, in clear and sharply cut words which can be readily comprehended and do not force one to resort to original and perhaps single specimens to learn what the author of the species really meant.

The end which we all wish ultimately to reach is a knowledge of how living plants act; but in the process of obtaining this knowledge it is necessary to call to our aid not only the physiologist, but also the systematist and the paleontologist; for there are many questions ultimately to be settled by the physiologist for which the information furnished by the systematist must serve as a basis, and the geological succession must be

supposed to throw some light on present conditions. It is no disparagement to systematic botany to say that it should look towards physiology as its necessary supplement; for, on the other hand, physiology must lean on systematic botany in attempting to solve many of its problems, and the scientific basis of both rests on histology, morphology, in the modern sense, and embryology. The qualifications needed in a physiologist are so different from those required in a systematist that no one is warranted in speaking of one as of a higher grade than the other. If it has become the fashion in some quarters to assign the systematist to a secondary place, it cannot be attributed to the fact that his work is necessarily inferior in quality, but is rather due to the fact that in too many cases systematists have failed to recognize what should be the legitimate aim of their work.

The utilitarian tendency is well shown by what has been said in speaking of bacteria and Saccharomycetes. Did time permit, and were the subject not one which would not readily be followed with patience by an audience at this late hour, other instances, especially in Ustilaginaceæ, might be given to illustrate further the point in question. The bacteriologist bases his species on grounds which he thinks best suited to enable him to group together intelligently the plants he is studying, and it is nothing to him that others say that his species are not species, but races. After all, the question whether certain forms are to be considered species or races is in many cases merely a question of how much or how little we know about them. The races of one generation of botanists often become the species of the next generation, who, as they study them more minutely and carefully, discover constant marks not previously recognized. As systematic botany develops in the future, it may very well become the study of races rather than species as we now consider them. In some cases, as in the Uredinaceæ, the time may be not far distant when this condition of things will be reached. We also feel warranted in believing that hereafter physiological characters will assume even a greater importance than at present in the characterization of species. If there are some among my hearers who do

not agree with me as to the importance to be attached to utility, I think that we shall all agree that in discussing the work of botanists in other departments than our own, it would not be wise to exact a rigid conformity to our individual conceptions of species as distinguished from races.

NOTES ON SOME EUROPEAN MUSEUMS.[1]

EDMUND OTIS HOVEY.

When the author was in Europe last year, for the purpose of attending the Seventh International Geological Congress, he improved the opportunities which presented themselves for visiting museums, paying especial attention to the departments of geology, mineralogy, and palæontology. On his return a somewhat detailed report on these matters was prepared for the authorities of the American Museum of Natural History, and this has been thought of sufficient general interest to warrant its publication. The order of presentation is essentially geographic, being very nearly that in which the museums were visited by the author. This discussion cannot claim to be complete, because the museums at Vienna and Munich are not included, these cities lying too far away from the route traversed to permit of being visited in the time at disposal.

Hildesheim. — This quaint mediæval city of northern Germany contains a large and valuable collection of various material in a confiscated monastery which has been remodeled to adapt it to museum purposes. It is called the "Roemer Museum" in honor of the public-spirited citizen who endowed it. Regarding the general museum there is not much to be said. There is much fine material on exhibition, but the general scheme of arrangement and classification and the installation are hampered by the limitations of the old monastery buildings. The director has, however, succeeded in bringing the geological department up to a high state of perfection and interest. The collection illustrating general geology consists at present of only about 350 hand specimens of rocks, but these are selected and displayed in such a manner that they give at a glance a very good idea of the most striking phenomena of the science. The collection in the cases is well supplemented by diagrams, charts, and photographs hanging upon the neighboring walls. The

[1] Read before Section E at the fiftieth anniversary meeting of the American Association for the Advancement of Science, Boston, August, 1898.

phenomena of nature thus illustrated embrace the action of mountain-building forces, of water, wind, and sand upon rock surfaces, and of volcanic activity of various kinds. The use of pictures is not only instructive, but is an addition to the attractiveness of the exhibit, and serves to call the attention of visitors to the specimens in the cases. The collection is well provided with descriptive and other labels. As proved by experience at Hildesheim, and also at the Natural History Museum in Paris, and at the Museum of Practical Geology, and the British Museum (Natural History) in London, such collections illustrating general geology may be made not only instructive, but attractive and somewhat popular as well. Here, even more than in some other departments of natural history, the popularity of the exhibit will depend largely upon the effectiveness of installation and arrangement and the clearness and completeness of labeling.

The Rock Collection embraces more than 1000 specimens on exhibition, and, besides igneous and other crystalline rocks, includes samples of sandstones, limestones, and other sedimentary rocks. The specimens consist, for the most part, of well-trimmed blocks about six by four by one to one and a half inches in dimensions. They are arranged in trays, and each is accompanied by a neat, clearly written, comprehensive label. The classification is according to a scheme of which the tabulated elaboration lies at convenient points in the cases, and may also be obtained with the printed guide. That such a collection of rocks is highly valuable to the student for systematic study goes without saying; but it is also useful to the general public for reference, because the knowledge, and consequently the literature, of the subject of petrography is rapidly increasing at the present time, and the inquiry for such collections is also on the increase. Wooden-framed cases are used exclusively throughout the museum.

Berlin.—The famous mineral collection of the Natural History Museum is arranged partly in wooden-framed cases with "A"-shaped tops, the exhibition specimens being arranged on narrow steps in these tops, while the base is provided with drawers for systematic storage. The cases display the minerals in an excel-

lent manner, but they are too high. The specimens on the top step are too far up for any but a very tall man to inspect, and such high cases interfere with the architectural effect of the room without any compensating gain in installation. Between the high cases there are narrow, flat-topped table cases, which contain the small, fine specimens and isolated crystals of the collection, the classification being strictly in accordance with that of the high cases. In the table cases white pasteboard trays with green edges are used to hold the specimens, and the effect is not pleasing; in the "A" cases the specimens rest directly upon the step shelves, which have raised edges. The inside of the "A" cases is painted a light color (either white or gray). Wire supports of various shapes are much used for the proper display of specimens, and with excellent effect. The large collection of meteorites and the mineral specimens which are too big for the cases are disposed about the hall without reference to classification.

The labels are all written by hand with India ink. An expert penman is employed for the work, and the labels are handsome in appearance, and less expensive there than printed labels would be. Such labels are in use throughout the museum, and are strongly to be recommended on account of their durability and appearance. To return to the mineral collection: the group labels are put into neat nickel frames which stand about four inches above the trays or the shelf. The individual labels are laid in trays in the table cases, but in the "A" cases are tacked to the front of the step, just beneath each specimen. Very few of the labels contain anything but the name of the species and the locality from which the specimen came; thus, "Fahlerz, Müsen, Westphalen." When the mineral has a "common name" recognized in Germany, that alone is used, as in the instance cited. Chemical formulæ, statements about crystalline form, etc., are relegated to the group labels. When specimens have come to the museum from some large or noted collection, that fact is indicated on the label.

The petrographic collection consists of representative hand specimens of all important kinds of rocks, arranged in table

cases, and is provided with many brief explanatory labels in addition to the individual label accompanying each specimen. Such phenomena as the effect produced on adjoining rocks by the heat of the igneous rocks when erupted or injected are fully illustrated by large, handsome specimens which have been very carefully collected and prepared for exhibition. The cases in this department also have wooden frames. The catalogue of each of these departments is in book form, and although a general catalogue has not yet been prepared, each specimen bears an accession number of such a kind that its exact location in the collection or in the storage drawers can be told at a glance.

Palæontological Collections. — The remains of animals and plants are in separate rooms. The collection of fossil animals is merely synoptic, only fine specimens being on exhibition, and includes vertebrates and invertebrates in one series, the arrangement being zoölogical. The hall is badly lighted, which greatly impairs the effect of the wonderful assemblage of fossil reptiles. Upright and table cases are used for the small and the particularly valuable specimens, but most of the large reptiles are displayed without any covering, except that some of them have a wire netting over them. The collection of fossil plants is in a well-lighted room. The specimens are very fine, and show that a collection illustrating palæobotany may be made attractive as well as instructive. A noteworthy feature of this room is a series of transparent sections of plants, mounted between glass plates and suspended in front of the windows, where one may readily examine them. This arrangement is not confined to the Berlin museum, however, and may be adapted to several classes of objects, *e.g.*, agates and corals.

Invertebrate Zoölogy. — The hall of invertebrate zoölogy is cased with iron-framed upright cases, which are about seven feet high and so arranged as to divide the room into alcoves. While a great amount of well-lighted exhibition space is thus obtained, the architectural effect of a large hall is lost by the arrangement. A new and very effective feature is a series of rectangular jars containing illustrative life groups in alcohol. Some of the groups represented are oysters and their surroundings,

mussels and theirs, and squids. In the molluscan collection many of the species have alcoholic preparations of the entire animals displayed in the cases beside the corresponding dry shells. Most of the insects on exhibition are in very shallow glass-covered boxes, which are held in frames in such a manner that they may be removed at will. These frames form "A"-shaped tops on table cases. Wings are mounted between glass plates and hung in the windows. A termite nest, more than six feet high, is one of the striking objects in this department.

Russia. — Although I visited museums in St. Petersburg, Moscow, Kazan, Perm, Nijni Tagilsk, Ekaterinburg, Kychtym, Oufa, Kharkow, and Tiflis, all can be dismissed with a few words, because, as a rule, the methods of installation in vogue are not to be recommended. Poorly lighted halls prevail, with flat-topped table cases and high upright and wall cases. These are usually made of pine, with small panes of glass, and inadequate protection from dust. The collections cannot be said to be well classified, except at the universities of Kazan, Moscow, and Kharkow, and at Tiflis. Commendation, however, rather than blame should be rendered the authorities of the smaller towns, because something, at any rate, has been done to get together and preserve objects of interest from the district in which the museum is located, — which is more than has been done by most towns of similar size and importance in countries which consider themselves ahead of Russia in such matters. The evils of faulty classification are illustrated in the mineral collection of the Imperial Mining Institute, in St. Petersburg. This collection has a world-wide reputation for the marvelous size, perfection, and beauty of some of its specimens, but it is difficult to find some of the most noted of these, because the minerals seem not to be arranged according to any system of classification that is recognized in western Europe, England, or America, even those of the same species not being kept together. Labels and locality cards are lacking from a large part of the collection, rendering it in so far useless to the average visitor and greatly lessening its value to the mineralogist.

Naples. — The only geological and mineralogical collections in Naples that are accessible to the public are contained in the

university buildings. They are primarily educational in purpose and are systematically arranged. They contain many fine specimens, among which may be mentioned a grand fossil palm from the Vincenza beds, near Verona, a volcanic "bomb," eighteen or twenty inches in diameter, from the crater rim of Vulcano, one of the Æolian islands, and a leucite crystal, nearly four inches in diameter, from Rocca Monfino. Flat-topped table cases with wooden frames are used in the geological rooms; in the mineralogical rooms such cases are supplemented by upright cases, in which, as so often happens, the upper shelves are far too high for utility. The specimens in the geological rooms are displayed in pasteboard trays, unless they are too large for this method of installation, while those in the mineralogical collection are mounted for the most part on wooden blocks. The Vesuvian collection of the celebrated mineralogist, Prof. C. Scacchi, is preserved in a separate room, to the detriment of the main collection. Such separate collections are the bane of a museum, interfering as they do with the uniform arrangement of the collection on a systematic plan.

Geneva.—The university at Geneva possesses a good museum of natural history in a well-lighted wing of its main building. The departments of geology, mineralogy, conchology, and invertebrate zoölogy, are the best. The rock collection is comprehensive, as one would expect it to be on the borders of the Alps. The hand specimens are displayed in white wooden trays with projecting bases for the labels. The effect is rather clumsy on account of the thickness of the edges of the trays. The de Saussure collection of quartz crystals from the Alps is famous and contains many fine specimens, but it is not well displayed, and poor installation detracts from any collection, no matter how beautiful the specimens may be. The Delessert collection of recent molluscs is here, containing many of Lamarck's types, but the types are not distinguished by means of a noticeable mark, as such important specimens should be. The shells are gummed to cards, a practice which is objectionable on account of the danger of fracture when the shell must be removed from the case for any purpose. The source from which the specimen has come to the museum is indicated by a

letter in the upper left-hand corner of the card on which the shell is mounted. Only a synoptic collection of the shells is on exhibition, — a very few examples of each species and not many species under each genus. In this museum again the upper shelves in the upright cases are much too high for the exhibition of anything but very large specimens which do not require close examination. The fossil shells are placed as near as possible to the groups of recent shells to which they are related.

Paris. Jardin des Plantes. Mineralogy. — The mineral collection is divided into three parts: the general collection; several special collections; some large specimens out of series. The classification recently proposed by Prof. P. Groth, of Munich, is followed in the general collection, with some modifications in minor details. The installation is not modern, the cases being narrow flat-topped table cases surmounted by shallow upright cases, and fully one-fourth of the collection being on shelves too high to be seen with any degree of satisfaction, if at all. Since, however, plans for a new building have already been drawn, it is not worth while to go into an extended criticism of what will soon be discarded. The system of labeling is very complete, each label bearing the name of the species or variety, with one or more synonyms, the chemical formula, the system of crystallization, the mode of occurrence, the locality, and the donor. The peculiar feature about the labels is the statement as to the mode of occurrence, and it is a good one. I quote a sample label from the printed visitor's guide to the collection:

THORITE.

Synonymes : *Thorine silicatée.*
Variétés : *Orangite, Uranothorite.*

Formule Chimique :
$Th\,Si\,O_4$.

Système Cristallin :
Quadratique.

Nature des Gisements :
Pegmatites, Syénites néphéliniques.

The italicized portion of the label is written in by hand, the rest being printed. The specimens are mounted on painted wooden blocks of a pearl gray color. The effect is rather cheap. The labels rest on pins on the sloping fronts of the blocks. Minerals like ruby silver, horn silver, the bromiodides, etc., which are liable to injury from exposure to direct sunlight or to very strong diffused daylight, are placed under covers made of orange brown glass. These, of course, do not improve the appearance of the cases, but they preserve the minerals, and they may be readily removed for the benefit of a student. The foundation of this general collection was laid more than a hundred years ago, hence it has had considerable time in which to grow to its present high state of perfection as to the number of species represented.

Special Collections. — There are seven of these: *A.* Collection of the minerals of France and her colonies. This contains in particular the types described in "The Mineralogy of France," by A. Lacroix, each species, however, being represented by only two specimens. The primary arrangement is by districts. *B.* Technological series. Under this head are brought together those minerals, cut or polished, which are used for ornamental purposes, jewelry, bric-a-brac, etc., such as agate, jade, jadeite, fluor spar, pagodite, etc. *C.* Collection to illustrate the occurrence of minerals. In the general collection the minerals are considered merely as minerals, but in this new collection they are regarded from the point of view of their formation, and are classified according to their occurrence and association in nature. This is a highly instructive and very interesting series, but thus far there have been placed on exhibition only the minerals of igneous rocks, those of sedimentary rocks which have been metamorphosed by contact with igneous rocks, and those of certain calcareous bands in gneiss. *D.* Collection of cut precious stones. The principal specimen in this gem collection is a beautiful blue sapphire weighing 132 carats and cut in rhombohedral form. The series of diamonds comprises about seventy-five crystals. The beauty of the gem collection is marred by its unsatisfactory installation. *E.* The Bischoffsheim collection of diamond crystals. This is kept separate from the

main gem collection. *F.* Collection of artificial minerals. This is in process of formation, a start having been made with a magnificent set of artificial rubies, which were manufactured by the Frémy-Verneuil process. *G.* The Haüy collection. This collection, which has great historical value, comprises several thousands of specimens labeled by the hand of the celebrated founder of crystallography, and is retained just as he left it. The great collection of meteorites is displayed in a case by itself. Most of the small specimens are mounted in wire holders attached to blocks. A printed label on the front of each block gives the history of the specimen in brief, *i.e.*, the kind of meteorite, the date of fall, when known, and the locality where found.

Geology. — The collection to illustrate stratigraphical geology occupies a series of flat-topped table cases running down the middle of the room containing the mineral collection. It is very full in specimens illustrating the geological features of central Europe. The Archæan is illustrated by means of specimens about 4 × 6 inches in size, of the principal varieties of rocks and of some of the results of dynamo-metamorphism. For the succeeding ages a synoptic collection of fossils is exhibited, together with specimens showing kinds of rocks, dynamic phenomena, etc. The arrangement is primarily chronologic, and under that is geographic. Plaster casts are introduced when good fossils are not available. Light-colored pasteboard trays are used for the specimens. The labeling is very complete. The gallery also of the mineral hall is devoted to geology, and contains a very large rock collection, besides the series of specimens upon which Daubrée and other French geologists have made their classic studies in experimental geology. In this part of the room also the labeling is very satisfactory. The cases, however, are far from dust-proof, and fully one-fourth of the geological as well as the mineralogical exhibit is too high or too low for satisfactory inspection.

Palæontology. — The extensive and important collections of vertebrate and invertebrate fossils occupy the main floor in a new building in the Jardin des Plantes, which was not yet open to the public at the time of my visit. Without going into a

detailed discussion of these celebrated collections, brief mention may be made of some points in their installation. The whole effect is rich, handsome, and pleasing, no expenditure of time or money having been spared by the government or the scientific *attachés* of the department to render the appearance of the hall as attractive as possible. Some might even say that this effort had been carried too far, characteristic French taste having been allowed full play. Tables and desk cases are of oak, and all are comparatively small. The exhibition part of the desk cases has a bronze frame, the bottom of which is covered with silk velour of a reddish terra-cotta color, and most of the specimens are mounted on tablets of heavy manila board ($\frac{1}{8}$ or $\frac{5}{32}$ inch thick) of a light brownish terra-cotta color. As a rule, the large specimens are placed directly upon the velour background without the use of tablets. Simple, handsome supports made of brass wire are much used in both the desk and the upright cases for mounting specimens in the proper attitudes. Minute specimens are cemented to glass squares or rectangles backed by cardboard of the same color as the velour, and the whole placed on the top of a wire support. As far as practicable, at least three specimens are used to illustrate each species of bivalve molluscs, an entire individual being fastened to the middle of the tablet in front, and the opposite detached valves being raised on wire supports on each side of it. Whenever needful or desirable, the specimens have been cut and polished to show the internal structure. The bronze-framed tops are excellent in that they are very tight and dust-proof, and that the frame presents the least possible obstruction to the light and to the view of the visitor, but those in the hall in question are hard to open, and they do not overhang the lower part of the cases. To have the upper part of a desk or table case project beyond the sides of the base for a certain distance (about four inches) is important, because exhibition space is gained thereby, visitors can see the specimens with greater convenience, and the bottom of the case is preserved from injury by boots. The upright cases have iron frames and a bolt lock similar to, if not identical with, the familiar Jenks lock. The backs of these cases are painted a

terra-cotta color of the same shade as the velour in the desk cases. The shelves are of plate glass, with the exception of the bottom one, which is of wood. The matter of labeling has been very carefully attended to, but types and figured specimens are not as prominently marked as they should be in every collection. The arrangement of the fossils is primarily stratigraphical, and then zoölogical by geographical provinces.

L'Ecole des Mines. — The collections of this famous school in all departments of geology are enormous. Wooden-framed cases are used throughout, but the installation is not very recent, and the writer does not know what the feeling of the authorities is toward cases with metal frames. The mineral collection is well labeled, but the classification is such that it is very difficult for a visitor, even though he know something of mineralogy, to find a given species. An attractive feature of the collection is the polished thin sections of minerals, such, for example, as agates, which are framed between glass and hung in the windows. There are many large, showy specimens in the collection, and these, for the most part, are arranged out of series in small rooms. They rest upon blocks, and are provided with printed labels. They are in high wall cases. There is a large and very interesting suite of artificial reproductions of minerals, representing the labors of Daubrée, St. Claire Deville, and others. The table cases have flat tops, and the specimens in them are displayed in pasteboard trays. The meteorite collection consists of small fragments, and is in white trays with blue edges. As would be expected in a mining school, materials of economic importance are well represented in the cases.

In the geological department the general rock collection is apparently very complete, and contains many handsome specimens. It is well arranged in upright cases, but it is defective in point of labels, and therefore is nearly useless to a visitor. The collection to illustrate general geology is very full, and is well arranged and labeled. It consists of a synoptic collection of rocks and fossils, and is classified by geographical provinces as well as by zoölogical subdivisions, under the primary stratigraphic arrangement. The best collection of all in point of

classification, and also in the manner of mounting the specimens, is that of palæontology. The arrangement is primarily zoölogical, and the completeness of the collection in certain departments, *e.g.*, Cephalopoda and Hippuritidæ, is impressive. Most of the specimens are mounted on tablets of manila board, some being kept in place by pins and some by cement. Very small specimens are attached to cards, which are then inserted into glass specimen tubes or vials, where they may be readily examined without being handled, and without danger of loss. The table cases are high and narrow from front to back, and have flat tops. The glass tops are arranged so that the front and sides are lifted up when the case is opened, leaving the specimens exposed as if they were on the top of a table. It is claimed that this is convenient, and that it renders the cases more nearly dust-proof than the usual method of opening. A device that may be recommended to museums in which the storage drawers under the cases were not provided with sliding glass tops when they were built is in use here. It is to groove (rabbet) the upper edge of the drawer all around, so that a glass plate of the right size may be slipped in as a cover. Thumb holes should be provided in the rabbet on two sides of the drawer to facilitate the removal of the glass cover.

London. The British Museum (Natural History).—A volume could be written about the methods of installation employed in different parts of this great institution. So many ideas have been tried here, and information on all points regarding desirable and undesirable methods of installation is so freely given by the officers in charge of the various departments, that it is not too much to say that this is the most important place in Europe for a person to visit who desires to learn what to do and what to leave undone in a museum. I can mention within the limits of these "Notes" only a few of the more striking features of the departments studied.

Palæontology.— Specimens are never crowded, much stress being laid upon the idea that it is better to have first-class specimens well displayed than it is to have all the material in the museum out on exhibition. Printed explanatory labels are full and numerous, and much use is made of drawings, diagrams,

and models, in the cases beside the specimens, to help to a clear understanding of structure. As examples of this feature, mention may be made of the crinoids, the brachiopods, and the cephalopods. Glass models of living cephalopods and corals are used in connection with the labels, explaining the structure of those groups of animals. Gaps in the series on exhibition are filled by drawings until the desired specimens can be obtained. Type and figured specimens are carefully and prominently marked with discs of emerald green paper gummed to them. Manila board tablets about $\frac{5}{32}$ of an inch thick, with light cream-colored surface, are now used in the cases. Pins are used for the most part instead of cement for keeping specimens in place. Species are divided off by means of strips of wood. The lower part of upright cases is utilized by putting in a false back and secondary shelves which bring the specimens close to the glass. None but large specimens, which do not require close inspection, are placed on the upper shelves of the upright cases. The drawers under the table cases are provided with sliding glass tops which protect their contents from dust and at the same time permit easy general inspection. The new floor cases have "A"-shaped tops, and for some forms of fossils which can be permanently attached to cards or mounted in trays or glass-topped boxes, these cases are excellent. A false bottom brings the specimens directly beneath the glass into good position for observation. All the cases have mahogany frames, metal frames not having found favor yet in this museum. The arrangement of the collection is primarily zoölogical, but under the zoölogical subdivisions the specimens are arranged according to geologic age and geographic provinces. A very large part of the material on hand is not on exhibition, being stored in accessible drawers as a study collection. The series of fossil plants is a very noteworthy portion of the department. One large gallery is devoted to the stratigraphic collection of British sedimentary rocks, and to nine collections of historic and palæontologic interest bearing upon the early history of the British Museum, and the study of geology and palæontology in Great Britain. The stratigraphic collection gives a continuous section of the sedi-

mentary deposits, from the most recent on the east coast to the most ancient on the west, and includes numerous small sections of the strata observed and recorded by various geologists in different parts of England. There is also a series of small maps, colored to show the exposed area of each geologic formation, and placed next to the case containing the specimens illustrating that formation. The most important of the nine "type" collections are those bearing the names of Sowerby, Gilbertson, S. V. Wood, F. E. Edwards, and Thomas Davidson. The last three alone would be enough to establish the preëminence of the museum in invertebrate palæontology.

Mineralogy.—The collection of minerals is probably the finest and most complete in the world. The aim of the trustees is to show all the definite mineral species that are known, in all their varieties of crystalline form, modes of occurrence, and associations with one another. They also aim to have specimens from all noteworthy localities, and it is a "special object that examples of each mineral species show its most complete development, whether in magnitude or perfection of crystals, in the color and limpid purity, or in any other important quality which may belong to it in its more exceptional occurrence." In a wall case just outside the entrance to the main mineral gallery there is a very attractive display of polished samples of some of the rocks and minerals which are used for ornamental purposes. The main hall or gallery is cased entirely with mahogany desk cases, except for four mahogany wall cases, two at each end of the room. The mineral collections include a series introductory to the study of minerals, embracing a set of specimens illustrating the growth of some of the ideas now considered fundamental in the science, and other sets of fine specimens showing the characters of minerals (their crystalline form, color, lustre, degree of transparency, streak, cleavage, etc.), and illustrating the terms used in their description; the systematic collection of species and varieties; enclosures in minerals; a series of crystals, natural and artificial; and a large number of pseudomorphs. The mineral specimens which are too large for exhibition in the desk cases are installed in wall cases in a room called the "pavilion," beyond

the main gallery. This pavilion also contains the collection of pseudomorphs and paramorphs, the Ruskin collection of forms of silica, and the famous collection of meteorites.

The specimens in the desk cases are mounted on tablets, and are never crowded. These tablets are of wood, with a very narrow rim, which is painted black. The main portion of the block is covered with a sheet of the finest quality of jeweler's cotton wool, which is held in place by being forced down into a groove provided for the purpose just within the raised rim. These tablets are very effective in appearance; they do not change color, and dust does not show readily on them, and specimens are not apt to slip on them. Group labels, and labels for particularly showy specimens, are printed with pen and India ink on white celluloid plates of appropriate size, and attached to the blocks on which the specimens rest, or are raised on suitable supports. When there are many specimens of the same species, they are grouped together within strips of wood of a given color. The use of these strips of colored wood gives a means of ready and rapid comparison. The strips are painted different colors on the two sides, so that one strip may answer for a partition. Minerals like proustite, the bromiodides, etc., which are liable to injury by long exposure to strong light, are covered with neat wooden boxes bearing the name of the species on the outside. Persons desiring to examine such specimens get permission to do so on application at the office of the department. A cloth screen rests on the top of the cases over other minerals which it is desirable to keep in the shade. This may be removed and replaced by the visitor himself. To provide against leaving cases unlocked, the locks are so arranged that the key cannot be removed from them without throwing the bolt. Cut gems are displayed in their systematic position in the general collection, there being no special "gem cases." The gem of the gems is a South African diamond crystal of very symmetrical form, weighing 130 carats. Much use is made of wire holders and supports for getting specimens into proper position for display. The system of classification followed is essentially that based on chemical composition and crystalline form, propounded by

Gustav Rose in 1852. Recent additions are exhibited for a time in a case provided for the purpose, before they are distributed in the general collection.

The great collection of rocks is arranged in the Mineral Gallery, on account of the close relationship between minerals and rocks, and consists of the regulation hand specimens about 4 x 6 inches in size, mounted on tablets in desk cases, and large specimens illustrating rock masses, installed in wall cases at one end of the room. A new feature of the collection, and one of the highest importance in such a branch of science as petrology, is the series of specimens introductory to the study of rocks. This series illustrates the gradual development of the science, and the terms used in the description of rocks as far as is practicable by means of specimens. Printed descriptions are displayed beside the specimens, so that they supplement each other in a very clear manner. It is not likely that the general public takes very much interest yet in such collections of rocks, but the demand for information on the subject of petrology is on the increase, as is shown by the testimony at the various museums mentioned in these notes, in which rock collections are on exhibition, and especially where the general collection is supplemented by an adequate introductory and explanatory series of specimens.

The series of guidebooks published by the British Museum is a highly commendable feature of the institution. These little books, of which fourteen are now issued for the various departments of natural history, are valuable aids to any one examining the collections. A few of them are intended merely as indexes to the collections described, but most of them are veritable text-books in popular though accurate language introductory to the department of science treated, making the most direct use from page to page of the specimens on exhibition in the cases. They are models of what explanatory guidebooks should be, and their prices are so low as to bring them within the means of all persons interested.

The Jermyn Street Museum.—The "Museum of Practical Geology," in Jermyn Street, contains the collection of the Geological Survey of the United Kingdom. In scope it is

confined to the British Isles and, as its name indicates, it seeks to show, as far as possible, the bearing of geology on every-day life. It contains much to illustrate the use of geological materials in art and industry, hence there are many manufactured articles on exhibition. The building is far too small for the proper display of the exhibition material on hand, and, therefore, the authorities cannot carry out their ideas regarding installation. The palæontological collection is very rich, and is arranged, as closely as may be, to illustrate the geological map of the kingdom in process of preparation by the survey. As at the British Museum, the types and figured specimens are marked by means of little discs of emerald green paper gummed conspicuously to them. The effect of a large part of the excellent collection of building stones is injured because the cubes are displayed in desk cases. Stratigraphic geology and petrology occupy a room together. The case introductory to the general rock collection contains a series of specimens to illustrate the meaning of the commonest terms employed in describing rocks, supplemented by enlarged microscopic drawings of thin sections of rocks. Such enlarged micro-drawings are also displayed beside many of the hand specimens in the general collection. A very interesting case in this room is that in which are displayed specimens to show the effects upon rocks of the surface action of various agents, such as ice, wind, and water. Photographs and other pictures form a very valuable adjunct to this series. In another compartment of the case one may see the effects which highly heated and molten rocks have produced upon the rocks with which they have come in contact. Cut gems are not wholly separated from the mineral species to which they belong, but are displayed in the case containing the principal show specimens of the mineral collection. The Ludlam collection is a series of very choice mineral specimens mounted on blocks in flat-topped, bronze-framed cases. New acquisitions to any department of the museum are displayed for a time by themselves before they are distributed to their permanent places.

Cambridge. The Woodwardian Museum. — The famous collections in this museum are so crowded into an unsatisfactory

building, that one gets very few hints as to general installation. The collections are entirely geological and palæontological, and the material is magnificent, especially that collected and prepared by Mr. Henry Keeping. Types and figured specimens are very carefully preserved, and a list of them was prepared and published as an octavo volume of 180 pages in 1891. These specimens are mounted on tablets of a different color from those used for other specimens. At one time pink was used, but now dark blue is employed. This method distinguishes the types with great readiness, to be sure, from the other specimens in a case or drawer, but it produces a bizarre effect upon the appearance of the collection, and specimens are in danger of losing their identity, if they are removed from their tablets for any reason, or if they become detached through accident. The tablets are made of manila board about $\frac{1}{8}$ of an inch thick. Specimens loaned to go out of the building always have a distinctive museum label gummed to them before they are taken away. The drawers used for storage and study collections are provided with sliding glass tops. Many interesting problems have been worked out or illustrated by means of the material in this museum; one of these is the arrangement of certain series of specimens to show the insensible gradation between related species and genera. Inasmuch as this museum is intended primarily for the student and the investigator, most of the collections are arranged with their convenience directly in view. The museum has a few special collections which must be kept together intact, by the provisions of their donors. The museum authorities have been striving for years to procure funds for a new building, and it is to be hoped that they will succeed before anything injurious happens to the valuable material under their care.

In closing these brief notes, the author wishes to disclaim having any thought that they are complete. He has not undertaken to mention all the good features of the museums visited, but has only tried to present some of the salient points that presented themselves in an all too hurried tour. Among the general considerations that come up most prominently out

of the mass of notes are the following: India ink is the only suitable medium to use for preparing pen-written labels, and great care must be exercised in the selection of type for printed labels, so that they may be readily and perfectly legible. Celluloid makes a handsome material on which to prepare certain showy labels, though some object to it on account of its inflammable nature. Certainly numbers of celluloid plates ought not to be stored together anywhere about a museum. Labels for individual specimens should be concise, clear, and brief, while those for groups should be more explanatory in character. Series introductory to the general collections are of the highest value in a public museum, and should be well supplied with diagrams, figures, charts, and explanatory labels, to make their meaning clear to the average visitor. Brass wire is a most useful thing for making supports of all forms for specimens and labels. The top and bottom shelves of most upright and wall cases can be well utilized only for large specimens and masses which do not require close inspection. Wooden blocks can be used to good advantage for the installation of specimens only in upright and wall cases, and then are best adapted to minerals. Tablets of manila board from about $\frac{5}{32}$ of an inch in thickness are an excellent mount for most fossils, though trays and glass-covered boxes and glass tubes are necessary for some forms. The manila tablets should be covered with paper of some light color that will not fade. Light cream color is now being used in the British Museum, but French gray is considered by most persons to be the most durable color. White is not at all lasting. Fragile specimens, or those with a thin epidermis, should not be cemented to tablets, but should be kept in place by means of pins. In general, it is best to mount specimens in such a manner as to permit of their ready removal for close examination or study. Metal frames for cases have found much favor on the Continent of Europe, and they certainly have a great advantage in that the framework presents the least possible obstruction to light and vision; but they are difficult to make and to handle, and they do not produce as good an achitectural effect in a gallery as wooden cases.

EDITORIAL.

Georg Baur. — In the recent death of Prof. Georg Baur, of Chicago University, science in America has met with a severe loss. In fact, since the death of Professor Cope there has been no one in our country who had a more extensive and a more accurate knowledge of vertebrates, living and fossil, than he. He came to America thoroughly trained by those masters, Leuckart and Zittel, and from his coming here until his death his work was continuous and important. The amount of work which he accomplished in his early years in this country is known only to few, but these few are fully aware that his contributions, especially to the study of fossil reptiles, were both numerous and of the highest importance. He was in reality the victim of that system against which this journal has always protested — he was not allowed to publish his discoveries over his own name. When the release came, Baur at once stepped into prominence, and had time spared him, he would soon have stood, in popular esteem, among the world's first paleontologists.

For many years Baur has been a firm friend of this journal. Many have been the contributions from his pen, but their value is to be estimated rather by their character than by their number. With the reorganization of the *American Naturalist* he was invited to assume charge of the department of vertebrate paleontology, and we felt that with his aid we would be able to maintain the high standard in that department which the journal had under Professor Cope. Continued ill-health, however, interfered with that active participation which he had expected to give. It was hoped that his return last spring to his home in Munich might bring renewed vigor, but he did not rally. The *American Naturalist* mourns its loss.

We are indebted for the following account to his brother-in-law, Ernst L. C. Schulz, of Munich, Bavaria : —

Born Jan. 4, 1859, at Weisswasser, Bohemia, where for a time his father was professor of mathematics, Georg Baur passed his youth in Hessen and Württemberg. He went through the Gymnasium at Stuttgart, and in 1878 entered the University at Munich, taking up especially the study of paleontology, geology, zoölogy, and mineralogy. In 1880 he went to Leipzig, where he studied under Credner and Leuckart. Two years later he returned to Munich, and there "made" his Doctor of Philosophy. He remained in Munich from 1882 to 1884 as the assistant of Professor von Kupffer, to whom he

was very much attached, and who in turn honored him with his friendship. In 1884 Dr. Baur accepted a call to Yale University, as assistant to Prof. O. C. Marsh. He resigned his position in 1890 to accept a place as Docent at Clark University, of Worcester, Mass. A year later, in 1891, he succeeded, after great difficulties, in organizing an expedition to the Galapagos Islands, leaving in May, and returning in October with a most valuable collection of the flora and fauna of these interesting islands. In 1892 he was called to Chicago University as assistant professor of comparative osteology and paleontology; he was made associate professor in 1895.

It was in September, 1897, that a serious breakdown of his health gave the first indication of mental overwork. Ever since the beginning of his career Dr. Baur had always been so intensely devoted to his studies and researches that almost no leisure hours remained for recreation (143 separate publications testify to his industry). A vacation of a few months, mostly spent at one of the pretty Wisconsin lakes, seemed to benefit him. Returning to Chicago in December, the physicians recommended either a sojourn in California or in Germany. The wish to be near his relatives made him decide for the old home, and with his family he left for Europe, the University generously granting a further leave of absence. The gravity of his illness (paralysis), already suspected in America, was at once recognized at Munich. The disease made such rapid progress that not many weeks after his return from a short stay in Southern Tyrol the transfer to an asylum was made necessary. The patient was not to suffer long; he died on June 25, not yet forty years of age, leaving a widow and four children.

The family have received many touching expressions of sympathy. At the grave Professor von Kupffer spoke feelingly, referring to "the great talents, the keen perception, the untiring industry of the departed, by which he had created for himself an honored place in anatomy and paleontology. Though young in years," he said, "Professor Baur was an authority in many fields. In remembrance of the time we worked together, of the friendship which united us, I lay down in deep sorrow this wreath of laurel."

Professor Baur has corresponded probably with every man of note in his particular branch of science, and many of them were his personal friends. Their sympathy, expressed in a great many letters, has been no small comfort and consolation to the bereaved family.

The departed belonged to various scientific societies in America; on February 28 of this year the New York Academy of Sciences elected him a corresponding member.